Integrated communication solution for oil and gas safety systems

By

Anders Johannessen & Arne Tangerås

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Abstract

The telecommunication system on today's oil installation consist of a number of different communication systems such as UHF radio (Ultra High Frequency), VHF radio (Very High Frequency), PABX (Private Automatic Branch eXchange), and PA (Public Address and Alarm). These communication systems have their own control panels. In addition these systems use various communication technologies for transportation of voice and data.

The operators have to deal with each of these control panels to operate these systems under normal and critical situations. In critical situations it can be crucial for the operators to act fast and correct to maintain control over the situation. This can be a demanding job especially when they have to deal with many different control panels simultaneously.

Normally these control panels have similar layout with similar functions. This makes it possible to integrate these systems and to use one common integrated user interface to operate these systems. This thesis is confined to deal with the integration of the PA system and the UHF system.

The Integrated Safety Systems (ISS) is primarily a safety system developed according to the NORSOK standard T-100 [1]. Besides, no single error shall cause this safety system to become dysfunctional.

One of the main tasks has been to evaluate a common communication technology for transportation of voice and data between the subsystems (PA and UHF) and the control panels. The different communication technologies we have evaluated for this purpose are various IP solutions, G.703 [2] solutions and a combination of these two solutions.

After evaluating six different proposals for a common transportation technology, we decided to continue our work with the combination solution. It is based on a centralized communication switch using G.703 for internal communication. The control panels and the communication switch are connected by a TCP/IP connection over Ethernet. This solution takes advantage of the OPC [3] technology for control and monitoring of the ISS. OPC is a standard developed for industrial automation systems, so this will be a new application for the technology.

Another task has been to make a proposal for a common integrated user interface for the PA system and the UHF system. This thesis describes the layout and functionality intended for the touch screen control panels, pushbutton control panels and the microphone stations.

In addition we have made four proposals for functional design specifications describing different parts of the ISS. The intention of the functional design specifications is to provide enough information on how to design the proposed solution.

Preface

This thesis concludes the two-year Master of Science program in Information and Communication Technology (ICT) at Agder University Collage (AUC), Faculty of Engineering and Science in Grimstad, Norway. The workload of this thesis equals 30 ECTS and the project has been carried out from January to June 2004.

The thesis has been developed in co-operation with ABB AS, Automation Technology Division in Bergen, Norway. In this context we would like to thank our supervisors at ABB, Engineer Ørjan Tveit and Master of Science Robert Fløholm, for great supervision and guidance throughout the project, and Pål Lillejord (software programmer) for his contribution on OPC and Delphi. We will also thank Assistant Professor Magne Arild Haglund, our supervisor at Agder University Collage, for great guidance on the report.

Grimstad, June 2004

Anders Johannessen

Arne Tangerås

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Abbreviations

CCTV .... Closed Circuit TV

COM .... Component Object Model

DCOM .... Distributed Component Object Model

F&G .... Fire & Gas

GUI .... Graphical User Interface

I/O .... Input/output

ISS .... Integrated Safety System

MS .... Microphone Station

MTBF .... Mean Time Between Failure

MTTR .... Mean Time To Repair

OLE .... Object Linking and Embedding

OPC .... OLE for process control

PA .... Public Address & Alarm

PABX .... Private Automatic Branch eXchange

PCB .... Printed Circuid Board

PPT .... Push To Talk

RNRP .... Redundant Network Routing Protocol

SAS .... Safety and automation system

SDK .... Standard Developers Kit

TDM .... Time Division Multiplexing

TMS .... Telecommunication Surveillance Monitoring System

UHF .... Ultra High Frequency

UPS .... Uninterruptable power supply

VAC .... Volt altemating current

VDC .... Volt direct current

VHF .... Very High Frequency

1 Introduction

1.1 Today's situation

The telecommunication system on today's oil installations consists of many different communication systems. Examples of these are UHF, VHF, PABX and PA. Since each system has its own control panel, the operators have to relate to a number of different user interfaces when operating these systems.

Today the operators have to control these systems manually under normal and in critical situations. As an example, a small fire in the drilling area on the installation will automatically set the PA system, but not the UHF system. If the operator wishes to go out live on various UHF channels she/he will first have to select these channels before she/he is ready to broadcast important messages on the UHF system. Similar examples can also be made from the other communication systems.

Each communication system also uses different technologies and wiring for transportation of voice and data. The cable installation work on oil installations is expensive, especially on offshore installations. The maintenance and operating cost related to this is also high.

1.2 Vision statement

The vision is to have one common user interface to control all the different communication systems, and one common technology for transportation of voice and data between these systems.

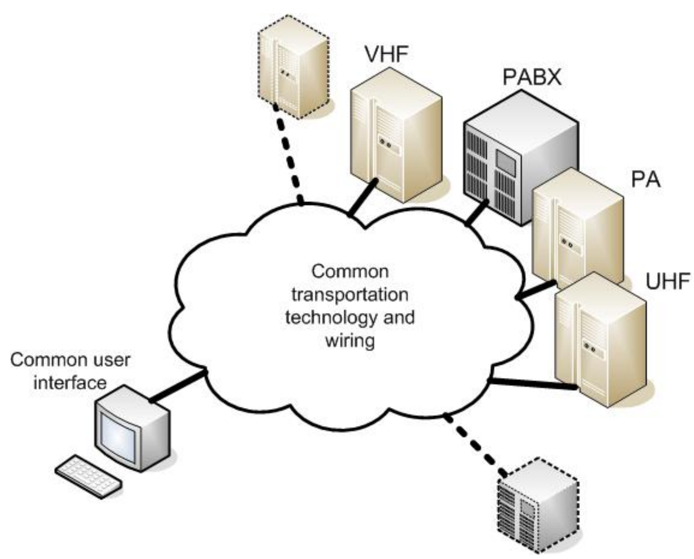

Figure 1-1: The vision

The communication systems on today's installations use many different types of wiring. Fibre, coax and cupper cables are all used for transportation of voice and data between the various communication systems. Often these cables run alongside each other on various locations on the installation. Another part of the vision is to replace these cables by a common transportation network running on the same set of cables. This will reduce the cost of maintenance and installation work, especially on offshore installations.

The intention is to provide the operators with a common user interface capable of controlling all the communication systems simultaneously. The functionality of the user interface shall be able to change dynamically according to various alarms and events received from the system. These dynamic changes are based on predefined configuration settings. This shall help the operators deal with critical situations by providing only the necessary functions. Compared with the example described in section 1.1, the behaviour of the system shall automatically change to predefined settings, according to incoming alarms and events. If a similar situation should occur, the predefined settings will select the right UHF channels and the operator can broadcast on both the PA system and the UHF system simultaneously.

As a part of the vision, this user interface shall be easy to implement in every control room throughout the installation and on other installations as well. This user interfaces shall provide identical functionality where implemented. In doing so it becomes possible to remotely control these systems from control rooms on other offshore installations or even from onshore.

1.3 Goal and objective

To limit the workload of the master thesis we will concentrate our study to the integration of the PA system and the UHF system. PA is an emergency alarm system used in critical situations. UHF is used for radio communication onboard the installation. If these systems shall behave properly, the TMS (Telecommunication Surveillance Monitoring System) system must also be included.

According to NORSOK [1] "*The PA system shall distribute alarm tones, emergency messages and routine messages to all or selected areas of the installation. In areas with a high acoustical noise level alarm tones and emergency messages shall be complemented by yellow flashing lights.*"

"*The UHF mobile radio and paging system shall provide two way voice communication and one way paging in all areas of the installation.*"

"Monitoring is a standard function. The TMS shall be able to receive and present spontaneous alarms from the telecom subsystems. The TMS shall have an alarm interface for transmission of alarms to a central control system (like the safety and automation system). Remote diagnostics and control may be included as an option where a telecom subsystem has such a function. The diagnostic software that is normally supplied together with the telecom subsystem should then be used."

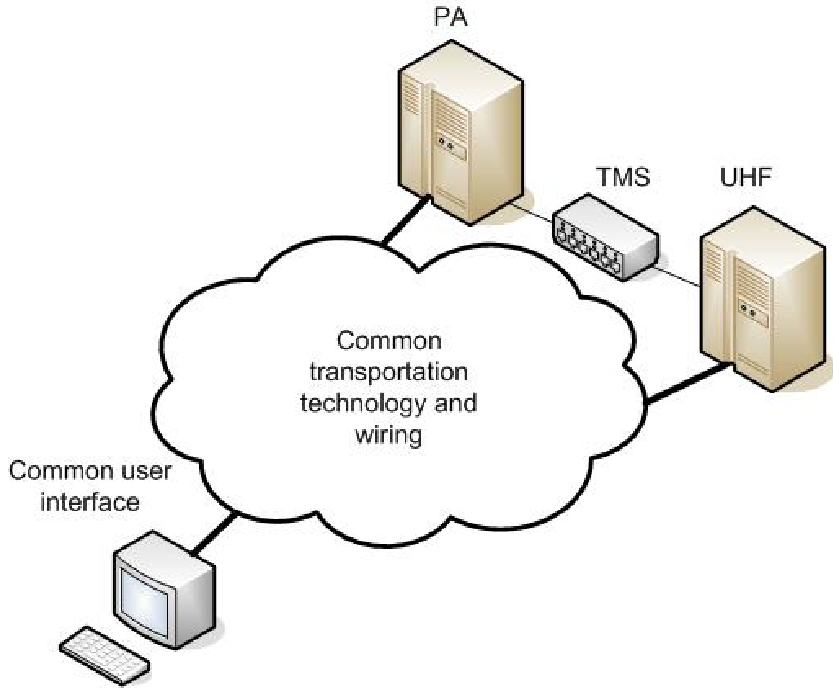

Figure 1-2: The vision of the Integrated Safety System

First we shall evaluate a common transportation technology between these systems and their relating control panels. The alternative technologies are TCP/IP, G.703 or a combination of these two technologies. We shall also evaluate solutions for a common user interface for use on touch screen and or push button control panels. Then we shall write proposals to functional specifications or new revisions of existing specifications describing the functionality of the new Integrated Safety System based on the selected transportation technology. If there is enough time left at the end of the project, we wish to make a demonstrator. This demonstrator shall test the most important functions in the ISS. We also hope to have time to integrate an OPC interface for the automation system.

1.4 Thesis definition

This is an English version of the thesis definition which originally was written in Norwegian (appendix E).

Thesis definition

Title: *Integrated solution for oil and gas safety communication systems*

Company: *ABB AS, Automation Technology Division, Telecommunication and Navy.*
Krokatjønnv. 11C. P.O. Box 3688 Fyllingsdalen, 5845 Bergen

Students: *Anders Johannessen, ajohan02@siving.ha.no, 97 78 57 65*
and Arne Tangerås, atange01@siving.hia.no, 48 18 32 90.

Supervisors: *Robert Fløholm (ABB), Ørjan Tveit (2nd supervisor, ABB)*
and Magne Arild Haglund (2nd supervisor, HiA).

Background:
On an oil installation today there are a number of different telecommunication systems. Examples of such systems are VHF, UHF, PA, CCTV and satellite systems. Since each of these systems has their own control panels, the operators have to relate to a number of different user interfaces. These systems also use different technologies for transportation of voice and data traffic. The vision is to have one common integrated user interface for all these systems and in addition have one common technology for transportation of voice and data.

Thesis definition:
To reduce the size of the thesis we are going to study the PA (Public Address and Alarms) and UHF (Ultra High Frequency Radio) systems.
First we shall evaluate a common transportation interface between these systems and their control panels. The alternatives are a G.703 interface, an IP-interface or a combination solution.
We shall also evaluate solutions of an integrated user interface for these systems to use on touch screen or pushbutton control panels.
Then we shall make proposals to detailed functional design specifications or revision existing specifications that describe the functionality of the new integrated safety system based on the selected transportation solution.
If there is enough time left we which to set up a demonstrator of the selected solution to test if this will work in practice according to the demands such a safety system requires. The demonstrator shall consist of a test version of the integrated user interface and the chosen solution. We also hope to have time to integrate an OPC interface toward the automation systems into the solution.

Conditions:
One condition we make is that we are able to use our own PC's or equivalent equipment at ABB. Another condition we make is that ABB is responsible for all purchase of equipment for use in the solution. We request ABB to assist with expertise and equipment in any solution outside the limitations of the Master Thesis.

1.5 About ABB

ABB is a leading company in power and automation technologies. They deliver industry specific products and services for the power, consumer, and process, oil and gas industry. The ABB group has about 113 000 employees world wide and are present in over 100 countries. Their strategy is to enable utility and industry consumers to improve performance while lowering the environmental impact. ABB has about 2000 employees in Norway with an annual turnover of 5 billion NOK. This thesis has been written in co-operation with ABB AS, Automation Technology Division, Telecommunication and Navy in Bergen, Norway. The Telecommunication and Navy division mainly delivers telecom solutions to navy and oil and gas industries.

1.6 Method of work

At the start of this thesis, we had no knowledge and experience with the safety systems described in this thesis. Since the literature on these systems is limited, we have learned about these systems through various discussions with the employees at ABB. Most of the information presented in this thesis is a result of these discussions. The technical parts of this report are influenced by the knowledge our supervisors have gained trough years of experience in the telecom industry. We have also received a great deal of information from other employees and through e-mail and telephone conversations with various equipment vendors. The development of the ISS have been disused on a daily basis with our supervisors. Besides, the design of the graphical user interface has been discussed with employees with experience in use of PA and UHF systems.

1.7 Report outline

Chapter 1 is an introduction to the master thesis. It shortly describes how telecommunication systems are structured on installations today, our vision statement, goals and objectives, and the thesis definition. This chapter concludes with a short presentation of ABB and the method of work. Chapter 2 presents various proposals for integrated safety systems, and a short presentation of the equipment related to these solutions. It also describes the evaluation of the different proposals, the elimination process, and finally a choice of solution. Chapter 3 and 4 provides a detailed description of our preferred solution for the integrated safety system. Chapter 3 describes the structure and functionality of the different parts of the ISS, while chapter 4 describes the user interfaces, their layout and functionality. Chapter 5 contains an overview of the development of the functional design specifications which describes the various parts of the ISS. The functional design specifications are presented in appendix A - D. Chapter 6 describes the development of the demonstrator. In chapter 7 we discuss the ISS, its benefits, disadvantages and its utility value. Chapter 8 provides some suggestions for further work, while the conclusion is presented in chapter 9.

2 Evaluation of communication technology

2.1 Introduction

A part of the thesis is to evaluate a transportation technology between the subsystems and their relating control panels. We were restricted by ABB to evaluate solutions based on TCP/IP and G.703 or a combination of these two technologies.

ABB wanted an independent evaluation of these technologies from someone outside the organization. The reason was an internal discussion regarding which of these technologies is the most suitable for this type of systems.

Those at ABB in favor of the TCP/IP solutions argued this is the most future-oriented solutions. Vendors of telecom equipment are developing various TCP/IP solutions to an exceeding extent. Equipment such as converters and switches are already communicating using IP and therefore the control panels should support this form of communication as well. Then all telecom equipment down to the subsystems can communicate using the same technology. This will reduce the cost of installation work on the installations. Those in favor of the G.703 solutions argued these solutions were the most reliable solutions. Previous solutions based on this technology have proven to be reliable. The PA system and the UHF system are used to deliver alarms and emergency messages and are therefore dependent on reliable voice and data delivery. Even though TCP ensure reliable data delivery data packages can be lost or delivered out of order. The throughput of data may also vary depending on the load of traffic experienced by the network. Benefits of the G.703 solutions are a constant throughput of data which are guaranteed to be delivered in the same order as they were generated. Besides, data is transmitted in a minimum of time delay.

Our supervisors at ABB tried not to influence us of their opinions in the evaluation process. We came up with different proposals to solutions. And our supervisors helped us with the development of these solutions. They also contributed with knowledge on various subject such as the requirements of safety systems used on various installations. We also used sources such as the NORSOK standard to ensure the different equipment used in the various solutions to satisfy these requirements. We read through numerous technical specifications to find detailed information about the different equipment.

After the development process we ended up with six different proposals to solutions for transportation of voice and data between the subsystems and the control panels. Among these solutions there were three TCP/IP based solutions, two G.703 solutions and one combination solution. We had to select one of these solutions and write functional design specifications for this solution. This section describes the different solution proposals and the selection process until we ended up with one final solution.

2.2 Solutions based on TCP/IP technology

2.2.1 Introduction

There are several reasons to why we want to evaluate possible solutions using TCP/IP technology over Ethernet. TCP/IP over Ethernet has evolved to be one of the most usual transportation technologies in PC networks. Until recently, this technology has not been much used in industrial automation and communication systems. In the last years different standards and technologies using Ethernet connections have been developed, and the range of products is constantly increasing. Besides the development of equipment are expected to increase exponentially in the following years.

Traditionally the control panels and the subsystems are communicating over a serial interface and an audio interface. The interfaces normally used for this purpose are RS-232, RS-422 or RS-485. The intention is to replace the traditional control panels with new common IP-compatible control panels, capable of controlling all the different subsystems over Ethernet. To achieve this converters are needed to convert audio and serial data to IP, and vice versa. We have discussed several interface converters. They are described in section 2.2.2.

We have made three proposals for TCP/IP based communication systems. They are described in detail in section 2.2.3, 2.2.4, and 2.2.5.

2.2.2 Interface converters

Currently, the subsystems have a serial data connection and an audio connection to their own control panels. The serial connection can be ether a RS-232, RS-422 or a RS-485 connection. Both data and audio are sent and received on the connections, so we will need to convert both serial data and audio to IP and vice versa.

Hopefully we can use one common converter capable of converting RS-232, RS-422, RS-485 and audio to IP. This will reduce the cost and need of equipment.

We have discussed several conversion solutions. One solution is to develop one or more new converters with all the necessary functionality and interfaces included. Another solution is to let one or more PCs being responsible for the conversion between the different interfaces. A better solution is probably to take advantage of existing equipment. There are a lot of interface converters available, but they are often just converting one interface to another. When we were looking for existing converters we found some CCTV (Closed Circuit TV) interface converters of interest. They are capable of converting one or more serial interfaces, audio and video to IP.

2.2.2.1 ABB interface converter:

ABB may need to develop an interface converter to achieve the necessary functionality for the converters. We have made a suggestion for functionality and requirements of such an interface converter.

This converter must support bi-directional RS-232, RS-422 and RS-485 serial data and bi-directional audio in the 300 Hz to 7 kHz (minimum) frequency range. There are several voice codecs available for this purpose, e.g. the Windows Media Encoder (WME) [4]. In the other end the converter must have a 100Base-TX Ethernet interface. These requirements meet the demands for the two separate IP network described in section 2.2.3 and 2.2.4. For the redundant IP solution described in section 2.2.5, the converter must in addition have two Ethernet interfaces and support for RNRP (Redundant Network Routing Protocol) [5]. RNRP is a protocol developed by ABB for handling redundancy in Ethernet.

2.2.2.2 PC based converters

It is possible to use one or more computers to convert serial data and audio to IP and vice versa. Many different PCI interface adapters are available for computers. By combining these interface cards it is possible to make a complete PC based converter system.

The ISS is a safety communication system. There are very strict requirement to uptime, MTBF (Mean Time Between Failure), and MTTR (Mean Time To Repair) for such systems. A computer contains a lot of components each increasing the possibility of failure to the system. Therefore a PC based converter may be a weak part of the system. It is possible to ensure uptime and redundancy in a computer, but this result in a very expensive and complex solution. Other solutions are more reliable and cheaper. Because of this we rejected this solution at an early stage.

2.2.2.3 CCTV converters

CCTV converters are normally used to connect analogue video cameras, audio equipment and control equipment, like remote door lockers, to an Ethernet for remote operation. Often there is one encoder and one decoder in each end of the Ethernet. We which to connect IP-compatible control panels directly to the Ethernet, so we need to make the decoding inside the control panels. Several CCTV vendors deliver a SDK or access to their CCTV-protocol for an extra cost. This makes it possible for us to connect the control panels to the CCTV converters.

The CCTV converters must fulfill these requirements:

- Support bi-directional RS-232, RS-422 and RS-485 data
- Support bi-directional audio
- Capable of encoding voice in the 300Hz to 7kHz (minimum) frequency range
- Preferably DC-power

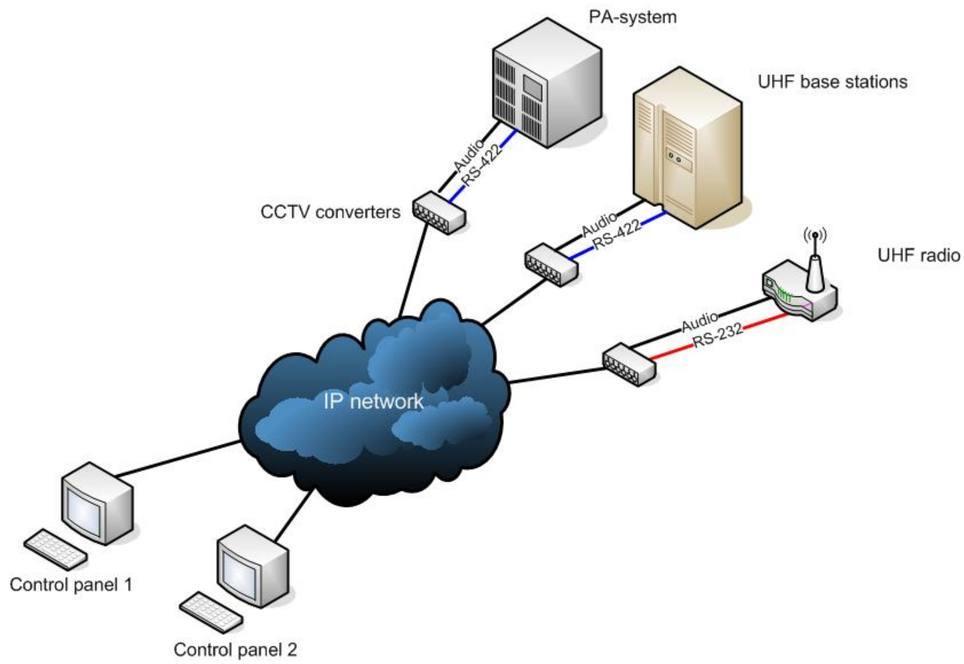

Figure 2-1: Use of CCTV converters

We have compared four different CCTV converters from different vendors to find the most suitable converter for this task.

Baxall IP codec:

The Baxall IP codec [6] are supporting bi-directional RS-232, RS-422 and RS-485 and bi-directional audio for duplex conversations. The converter makes use of G.711 [7] audio encoding. G.711 is an international standard encoding telephone audio on a 64kbps channel, but can only encode frequencies between 0 and 4 kHz. As mentioned above we need to convert frequencies between 300Hz and a minimum of 7 kHz.

Table 2-1: Baxall IP codec

Baxall IP Codec		
	Description	*Status*
Audio	Bi-directional 300 Hz to > 7 kHz Audio interface: Line in/Line out	Yes No Yes/Yes
Data	RS-232, RS-422, RS-485	Yes
Network	LAN data rate: 8kbps up to 1,5 Mbps	Yes
Power supply	120 to 240 VAC 12 VDC	Yes Yes

Baxall offers a SDK that let customers develop their own applications capable of communicating with different Baxall products. With this SDK we can make an application connecting the control panels to all the different equipment. Built-in functions for microphone and loudspeaker makes it possible to establish a two-way conversation between the IP codecs and the control panel application. Besides, the SDK can be used to make a GUI for the application.

The IP codec is available in three different versions, with a single codec, dual codecs or with quad codecs. Because of safety reasons the single IP-codec will be the most likely version to use. If the power supply fail, just one system fails, not two or four.

The following prices are given by Baxall Limited.

Single encoder/decoder:	£583 boxed, £850 rack
Dual encoder/decoder:	£1700
Quad encoder/decoder:	£3200
SDK:	£10.000

Hirschmann R-VIP T:

The Hirschmann R-VIP T [8] is also a converter used to connect serial equipment to an Ethernet in a CCTV system. This converter works the same way as the Baxall IP-codec. It can transmit video, bi-directional audio and bi-directional data from different serial interfaces over an Ethernet. It also uses the G.711 audio compression which results in a too poor audio signal. As already mentioned, the G.711 audio compression does not fulfill the requirements (300 Hz – 7 kHz) to the audio quality.

Table 2-2: Hirschmann R-VIP T

Hirschmann R-VIP T		
	Description	*Status*
Audio	Bi-directional 300Hz to > 7kHz Audio interface: Line in/Line out	Yes No Yes/Yes
Data	RS-232, RS-422, RS-485	Yes
Network	LAN data rate: 10 kBit/s up to 1 MBit/s	Yes
Power supply	120 to 240 V AC 12 V DC	Yes Yes

According to Profitek AS, the Hirschmann R-VIP T will cost approximately 18.700, - NOK exclusive VAT.

VCS VideoJet 1000/VIP 1000:

The VCS VideoJet 1000 [9] and VIP 1000 [10] provide real time video and audio with simultaneous MPEG-2 and MPEG-4 encoding. They are developed for broadcasting high quality video and audio over Ethernet.

The MPEG-2 encoder provides 300 Hz to 10 kHz audio. VCS VideoJet 1000 and VIP 1000 are the only encoders supporting this frequency range we have found.

Table 2-3: VCS VideoJet 1000 / VIP 1000

VCS VideoJet 1000 / VIP 1000		
	Description	*Status*
Audio	Bi-directional 300Hz to > 7kHz Line in/Line out	Yes Yes Yes/Yes
Data	RS-232, RS-422, RS-485	Yes
Network	LAN data rate: 1 MBit/s up to 8 MBit/s	Yes
Power supply	90 to 250 VAC (VideoJet 1000) 12 – 24 VDC (VIP 1000)	Yes Yes

A SDK [11] is available for the VCS equipment which let us make an application communicating with the VideoJet 1000 or VIP 1000.

According to Profitek AS a VCS VideoJet 1000 will cost approximately 30.000, - NOK exclusive VAT. A price for the VIP 1000 was not given.

2.2.2.4 Summary

The PC-converter solution was early rejected because of its complexity and expected costs. Taking advantage of existing CCTV converters is probably the simplest and best solution. Most of these converters do not meet the requirement for 7 kHz audio quality. Only the VCS VideoJet 1000 and VCS VIP 1000 meet this requirement. They support bi-directional audio in the 300 Hz – 10 kHz frequency range with line-in and line-out, and bi-directional RS-232/RS-422/RS-485 data. If the converter needs extra properties, like dual Ethernet and support for RNRP, the only solution will probably be to develop a new converter.

Table 2-4: Comparison of converters

	300 Hz – 7 kHz	Bi-directional Line-in/Line-out	Serial interface	Power supply	Price
Baxall IP codec	No	Yes	RS-232 RS-422 RS-485	120-240 VAC 12 VDC	£583 - £3200
Hirschmann R-VIP T	No	Yes	RS-232 RS-422 RS-486	120-240 VAC 12 VDC	18.700 NOK
VCS VideoJet 1000	Yes	Yes	RS-232 RS-422 RS-487	90-250 VAC 12-24 VDC	30.000 NOK
VCS VIP 1000	Yes	Yes	RS-232 RS-422 RS-488	90-250 VAC 12-24 VDC	NA

2.2.3 Two separate IP networks, solution 1

The two separate IP network, solution 1, is based on two networks with identical structure. One of the LANs represents system A, and the other LAN represents system B. This solution requires two sets of subsystems. System A and system B are both adequate systems with all the functionality required included in both the systems. System A is the main system, used under normal circumstances. System B is a backup-system, and is only used if there is something wrong with system A. The control panels must be connected to both system A and system B. This means the control panels must have two Ethernet interfaces.

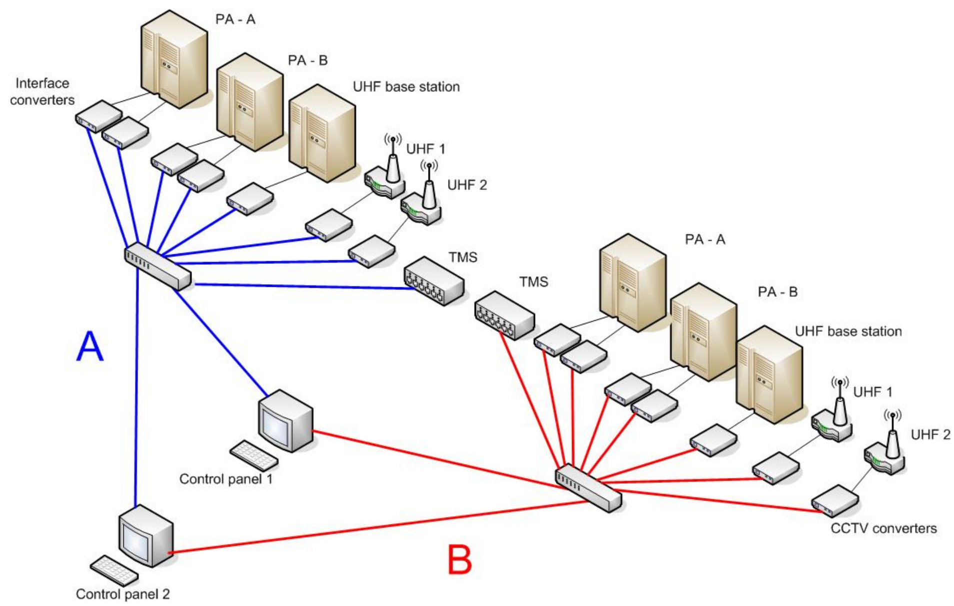

Figure 2-2: Two separate IP networks, solution 1

Based on status and error messages from the TMS and connection monitoring, the control panels shall switch between the networks. Any single failure shall make the control panels switch network. The control panels shall never communicate over both the networks simultaneously.

Each set of subsystems shall include two PA subsystems because of redundancy, one common UHF base station for all the control panels and one stand-alone UHF radio for each connected control panel. This will give the operator full flexibility over the radio. New equipment must be included in both system A and system B.

The PA-subsystems have one connection point to each control panel. This will result in the need of one interface converter for each control panel on each PA subsystem. The exact number of needed interface converters can be calculated after this equation (This equation is just calculating the use of PA systems, UHF systems and TMS systems).

Number of interface converters = ((number of CP * 3) + 1) * 2

Advantages:
Two separate networks and a double set of subsystems will make the system reliable. By having two separate systems, there will always be a backup system if the currently used system fails.

Disadvantages:
This solution consists of a lot of extra equipment, both subsystems and interface converters. This will result in a very expensive solution. On installations there are often limited areas for radio antennas. So a doubling of UHF-equipment is not ideal. Besides, combiners for connecting more UHF-radios to a common antenna are expensive equipment. Both PA - A and PA - B shall be used simultaneously, so data from the control panels have to be synchronized before they are sent over the PA - systems.

2.2.4 Two separate IP networks, solution 2

In this solution we also have two separate networks. The main difference from solution 1 is that this solution only has one set of subsystems. The subsystems are connected to both the networks. This will reduce both the need and cost of subsystem equipment.

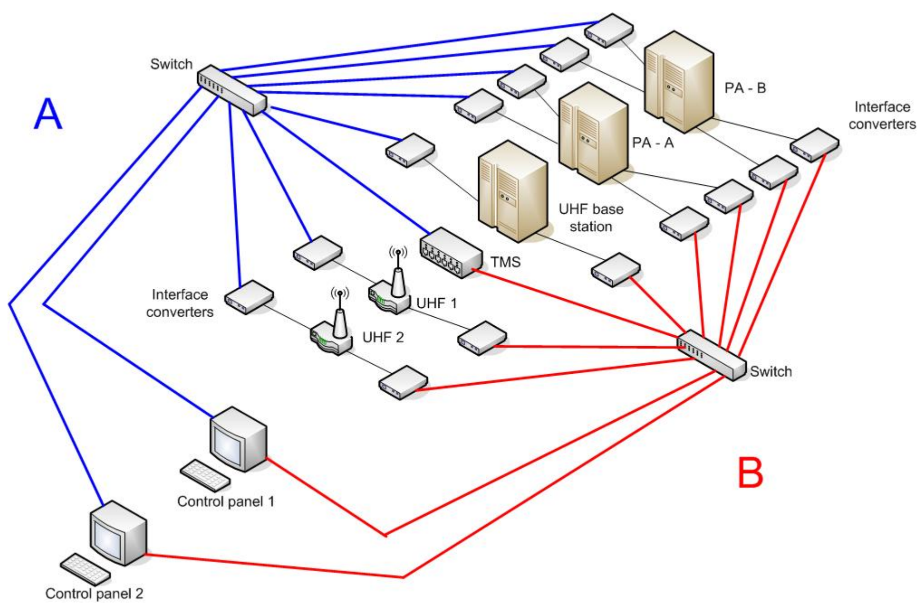

Figure 2-3: Two separate IP networks, solution 2

The A-system will be the primary network, and the B-system will be a backup network. The control panels shall switch between the networks based on status and error messages from the TMS and connection monitoring. Any single failure shall force the control panels to switch network.

This solution shall include two PA-subsystems because of redundancy, one common UHF base station for all the control panels and one stand-alone UHF radio for each connected control panel. This will give the operator full flexibility over the radio.

The subsystems have to support double serial connections. Two interface converters, one per network, will be connected to each connection point on the subsystems. The PA-subsystems have one connection point to each control panel. This will result in the need of one interface converter for each control panel on each PA-subsystem. The exact number of needed interface converters can be calculated after this equation (This equation is just calculating for the use of PA systems, UHF systems and TMS system).

$$\text{Number of interface converters} = ((\text{number of CP} * 3) + 1) * 2$$

Advantages:
This solution needs half as many subsystems as solution 1. This will reduce the costs and the need for equipment. Two separate networks will ensure a redundant connection to the subsystems.

Disadvantages:
Only the equipment with specified requirements to redundancy is absolutely failsafe. This will be the PA-system in this solution. An error in one of the UHF-systems will result in downtime for the respective equipment. This solution needs the same number of interface converters as the solution 1. Both PA-A and PA-B shall be used simultaneously, so data from the control panels have to be synchronized before they are sent over the PA-systems.

2.2.5 Redundant IP network

This solution is based on a redundant network-topology. All the control panels and the subsystems are connected via two Ethernet interfaces. The communication over the network is managed by a redundancy protocol supported by all the connected equipment.

ABB has developed a redundancy protocol called RNRP. By implementing this protocol into the control panels, the interface converters, the TMS and other IP based subsystems, the network should be resistant to any single failure. There shall be two PA-subsystems, one common UHF base station for the control panels and one stand-alone UHF radio for each control panel. There are no existing interface converters available supporting RNRP, so ABB will probably has to make their own. The control panels do not need to switch between the two networks. This is handled by the RNRP-protocol.

The PA-subsystems have one connection point to each control panel. This will result in the need of one interface converter for each control panel on each PA-subsystem. The exact number of needed interface converters can be calculated after this equation (This equation is just calculating for the use of PA systems, UHF systems and a TMS system).

Number of interface converters = (number of CP * 3) + 1

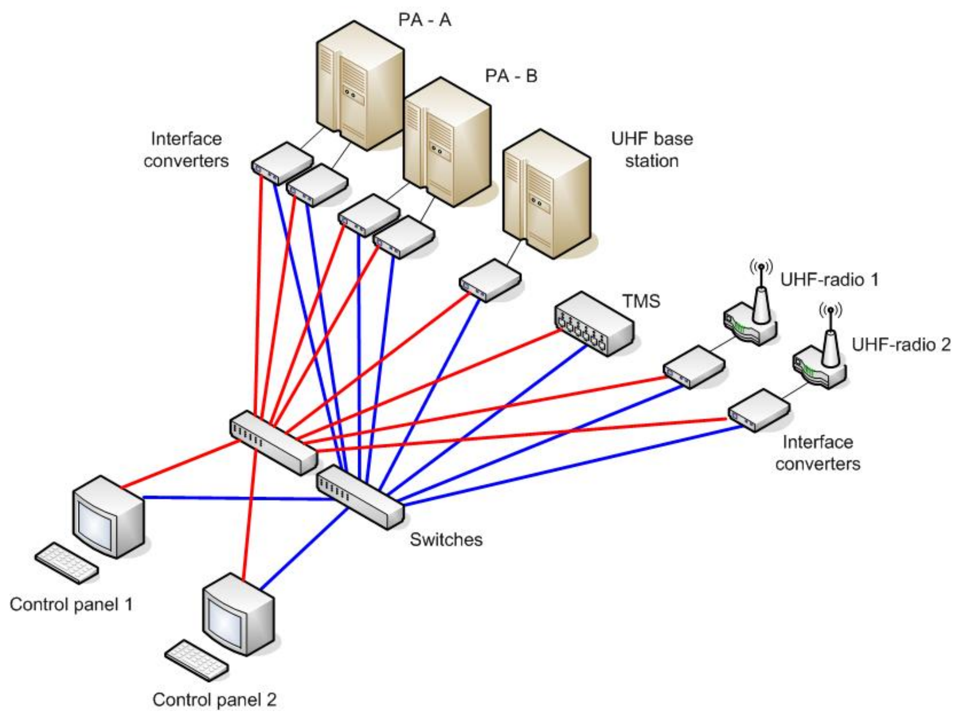

Figure 2-4: Redundant IP solution

Advantages:
This solution requires a minimum of subsystems and interface converters, which reduce the costs and need of space in the equipment rooms. The redundant network topology ensures a reliable network connection.

Disadvantages:
Only the equipment with specified requirements to redundancy is absolutely failsafe. This will be the PA -system in this solution. An error in one of the UHF-systems will result in downtime for the respective equipment. Both PA -A and PA - B shall be used simultaneously, so data from the control panels have to be synchronized before they are sent over the PA - systems.

2.3 Solutions based on G.703 technology

2.3.1 Introduction

In this section we describe two solutions based on the G.703 technology, one star topology solution and one ring topology solution.

The G.703 Recommendation [2] specifies the physical and electrical characteristics of the interfaces at hierarchical bit rates as described in the ITU-T (CCITT) G.702 Recommendation [12]. The G.703 standard originally described voice over digital networks associated with the PCM standard. According to PCM, voice to digital conversion requires a bandwidth of 64 kbit/s. The 64 kbit time slot is the basic unit of the G.703 standard. The ITU-T G.704 Recommendation [13] is the framing specification for G.703. A G.704 time frame is divided into 32 channels or time slots of 64kbit making it a 2048 kbit time frame. The first time slot is normally used for synchronization and the 16th time slot is normally used for signaling. The rest of the 30 time slots are free to use for data. The G.703 standard with G.704 framing is often referred to as Structured G.703. It seems to us that G.703 has become a technical term for Structured G.703 in the telecom environment. As a precaution, we use the technical term G.703 for Structured G.703 in this thesis.

2.3.2 Interface converters

ABB has already developed equipment converting serial and audio data to G.703 and vice versa used in other solutions. With minor adjustments, these converters can be used in our G.703 solutions described in the following sections.

2.3.3 The Star Topology

The star topology has some beneficial features. Every component connected to the switch has its own link and are therefore able to transmit at full link speed (bandwidth) provided by the switch. New components can be connected directly to the switch without interfering with already connected components.

We briefly discussed how to use a switch based on G.703 technology in a star topology. The intention was to use a centralized switch with similar functionality as a PABX system. The components connected to this switch normally use different standards for communication, therefore converters are needed to convert these data to the G.703 standard. The idea was to use a G.703 link to transmit data between the switch and the converters. The switch shall be responsible for synchronization and allocation of time slots.

One of our supervisors tipped us about a switch at Mearsk Data Defense which according to him should provide similar functionality we were looking for in the switch in The Star Topology solution. We sent an e-mail to Mearsk Data Defense asking for more information on this switch. Unfortunately we did not receive any information from Mearsk Data Defense.

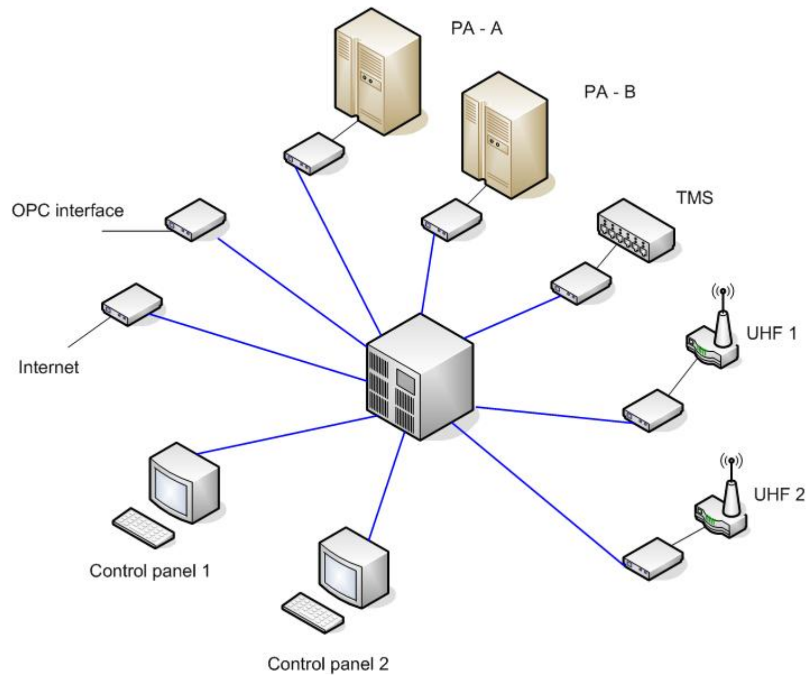

Figure 2-5: The Star Topology

Advantages
Using the star topology makes it easy to connect additional component or to replace old components with new components without interfering with already connected components. In this solution a G.703 connection is set up between the control panels and the converters via the switch. This results in synchronized and reliable transmission between the control panels and the converters.

Disadvantages
If a failure occurs in the centralized switch, the system would become dysfunctional unless the components are connected to two or more switches.

2.3.4 The Ring Topology

The Ring Topology solution is inspired by a similar solution developed by ABB intended for the Norwegian Navy newest frigate vessels. Every component in this system is connected to a redundant fiber ring by a converter. The fiber ring consists of two optical fiber conductors. Only one of the conductors is in use under normal condition. The purpose of the other conductor is to obtain redundancy. If a failure should occur to the operational conductor data is switched over on the other conductor and sent in the opposite direction. Each converter is given a unique ID. The converter with the lowest ID is responsible for synchronization. Each converter includes two PCBs (Printed Circuit Board), a main card and a baby card. The main card includes the logic needed for processing data transmitted and received within the ring. The main card is identical in all the different converters. The baby card consists of different electrical interfaces depending on the functionality it shall provide to the equipment connected to the converter.

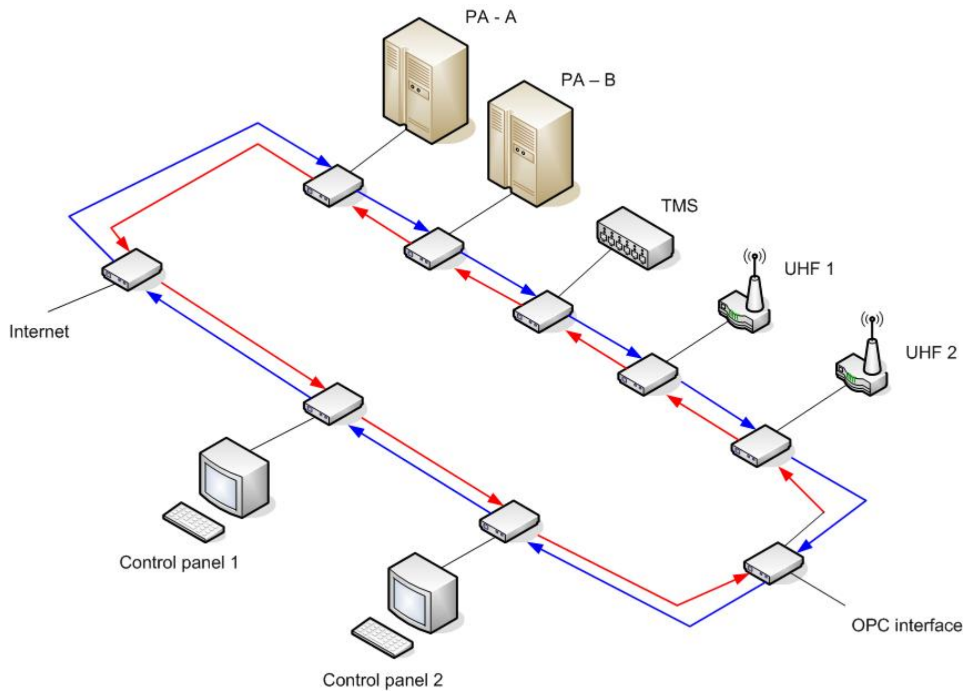

Figure 2-6: The Ring Topology

The main reason we got interested in this solution was the fact that ABB earlier had developed a similar solution. We could use the converters developed for the ABB solution and thereby reduce the cost on the converters. In addition the employees at ABB had experience from the ABB solution. We could take advantage of their knowledge, and increase the possibility to achieve a successful solution. ABB have developed the converters in co-operation with an external developer. This makes this solution dependent on the external developer.

Advantages
We know a similar system is operational. The personnel at ABB have knowledge from the development of a similar system and we hoped to benefit from their experience. Using the same converters for this solution as used for the ABB solution reduces the cost related to the converters. Data control and synchronization of data are beneficial features of the G.703 technology.

Disadvantages
The ring topology solution includes converters from an external developer. If this developer should be unable to deliver these converters, the solution will suffer from this next time a converter has to be replaced.

2.4 The combination solution

ABB is currently developing a switch for controlling communication between equipment with different communication interfaces. It turned out this switch has similar functionality as we were looking for in our solution. We decided to use this switch in one of the proposals for the ISS. Since this switch is still under construction by ABB, we have made a proposal for the functionality the switch shall provide. This means it presumably have to be done modifications to the switch to suite our proposal to the combination solution. The intention is not to develop a new switch, which would have been requiring too much work even for a master thesis, but to theoretical describe the functionality the switch shall provide.

G.703 technology is used for internal communication in the switch. This ensures reliable and synchronized communication between the connected equipment. Data received from the control panels are delivered to several subsystems without interference, loss of data and with a minimum of time delay. A G.703 link is used to connect several switches together. This result in the possibilities for integrating subsystems connected to several switches in a synchronized switching system.

We want to make PC based control panels because of the complexity the common control panels shall provide. The most common communication technology for computers is probably IP over Ethernet. Therefore we wish to use an Ethernet for connecting the control panels to the communication switch. This also makes it easy to connect new control panels and control panels from other networks to the system. This is a combination solution because it combines the use of both G.703 and IP technology.

To ensure redundancy, at least two communication switches must be included in the solution. Besides, subsystems requiring redundancy is connected to each switch. There shall also be redundancy in the Ethernet and the control panels needs two connections to the Ethernet.

The ISS make use of OPC (OLE for Process Control) technology [14] for controlling and monitoring the entire system. OPC is mainly used for transmission of process data in automation systems. The communication switches shall include an OPC server and the control panels shall include an OPC client. The servers are capable of controlling the switching matrix and subsystems based on commands from the control panels. Besides, the servers shall include monitoring values for the switches and the subsystems.

The structure of the combination solution is divided into three levels. The first level is the operator panels, the second level contains the two communication switches and the third level contains the subsystems (PA, UHF, and TMS).

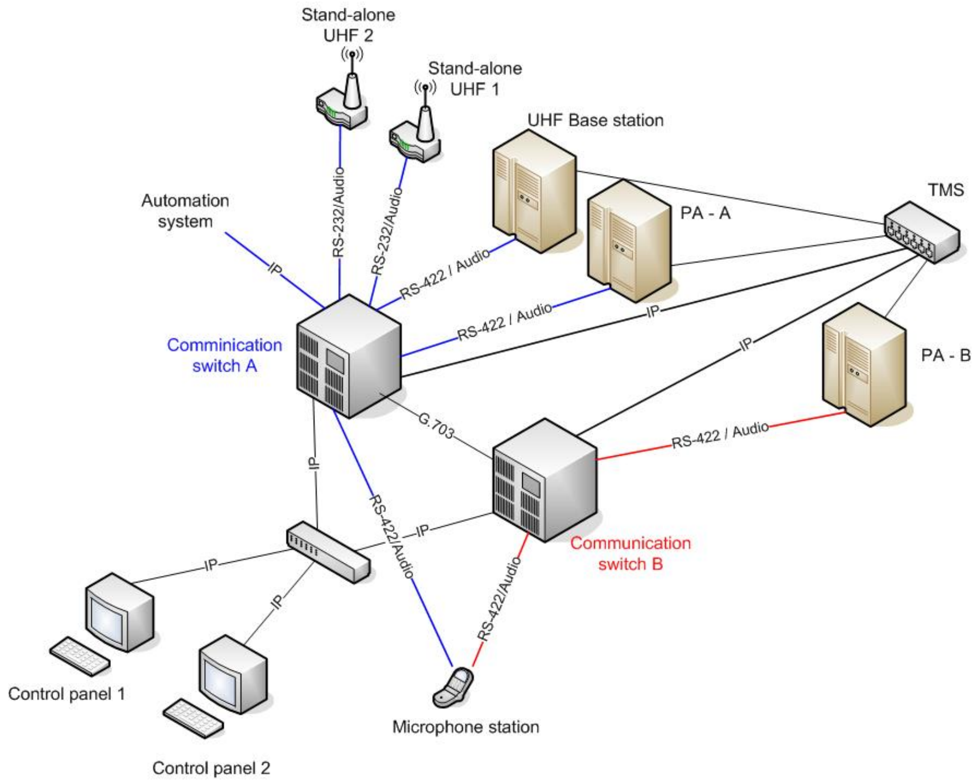

Figure 2-7: The combination solution

Advantages
The combination solution does not require any converters since the communication switch itself converts and switches data between the subsystems and their relating control panels. It is relatively easy to connect additional equipment. The switch has a capacity of switching between 30 to 120 different ports making it relatively easy to interconnect additional equipment without interfering with already connected equipment. ABB themselves is engaged in the development of the switch. This is an ABB proprietary solution which gives ABB full control over the different parts of the solution, without having to relay on products from different suppliers.

Disadvantages
It remains to see if this switch will satisfy the requirements of safety systems, since the development of the switch is not finished yet. Due to the fact that the swish is jet under construction we do not have a total overview of interfaces and functionality it provides.

2.5 The elimination process

After going through the development process we ended up with six proposals to solutions as described in the previous section. On our weekly briefing sessions with our supervisors at ABB, we discussed the development of the master thesis according to the time schedule we had developed in advance. After coming up with the six proposals to different solutions we decided to end the development process and start the elimination process. By the elimination process we mean the process of discarding solutions one by one until one final solution remained. Our supervisor recommended us to make a list of advantages and disadvantages of each solution, and according to this list, discard solutions one by one. This section describes the different stages of the elimination process and how we ended up with one final solution.

At the first stage of the elimination process we discarded the star topology solution based on the G.703 technology and the two separate IP networks, solution 1 based on TCP/IP technology. The reason why we discarded the star topology solution was the lack of information we had on this solution. We were unsuccessful to receive more information on this switch from Mearsk Data Defense. Compared to the other IP solutions the two separate IP networks, solution 1 requires twice as many subsystems. This results in more space needed for the subsystems in the equipment rooms, more antennas and higher costs. Due to limited space on installations the amount of antennas should be kept to an absolute minimum. Based on these conclusions we decided to discard this solution.

The next two solutions we discarded was the G.703 based ring topology solution and the IP solution called two separate IP networks, solution 2. The two separate IP networks solution 2 was discarded because it required twice as many converters as the redundant IP solution. The redundant IP solution which is constructed of one single network makes use of the RNRP protocol to switch data if faults should occur. If a failure occurs in the two separate IP networks, solution 2, the control panels need to switch data over to the other network. According to this the two separate IP networks, solution 2, is a more complicated solution compared with the redundant IP solution, and we therefore decided to discard this solution. We decided to discard the ring topology solution because the combination solution already had a better suited topology for the purpose this type of solutions shall maintain. Besides, this solution requires converters developed from a specific supplier, making ABB dependent on this supplier. One goal for these solutions has been to develop solutions which are independent of sub suppliers. In addition the master thesis shall include elements of new research or new methods. We felt the ring topology solution had to few elements to fulfill these requirements.

At the end of the elimination process we had reduced the number of solution from six to two. Now we had to decide between the redundant IP solution and the combination solution. We needed extra time to decide which solution to select, because we needed more information on the RNRP protocol used in the redundant IP solution. To get more information on the RNRP protocol we had to e-mail employees outside the division we worked at. Unfortunately we did not receive enough information on this protocol by the time we had to make a final decision. With the lack or information on the RNRP protocol we decided to proceed with the combination solution.

The combination solution has many advantages compared to the other solutions we discarded. First of all, no converters are needed because the switch used in this solution is capable of switching data between the connected equipment. Second, this solution is developed using equipment licensed by ABB. Previously solutions developed by ABB were dependent on other suppliers. The combination solution is independent, meaning ABB no longer has to relay on other suppliers, but can decide to develop the solution themselves or in cooperation with any preferred vendor.

2.6 Summary

In this chapter we have presented six different proposals for an integrated safety system; three IP solutions, two G.703 solutions and one combination solution. The IP solutions and the G.703 solutions require use of interface converters, so we have also discussed different converter solutions. It turned out that most existing IP converter solutions didn't fulfill the requirement to the 7 kHz audio quality. The different ISS proposals were evaluated, and discarded one by one. The final proposal was the combination solution which we mean is the most appropriate proposal for the ISS.

3 The Integrated Safety System

3.1 Introduction

After going through the elimination process described in the previous chapter we decided to continue our work based on the combination solution. This is probably the most reliable solution for an integrated safety communication system.

The Integrated Safety System is based on the combination solution described in section 2.4, but several changes and improvements have been made. The system can still be divided into three main levels; the control panels, the communication switches and the subsystems. This section describes the gray parts in the Figure 3-1.

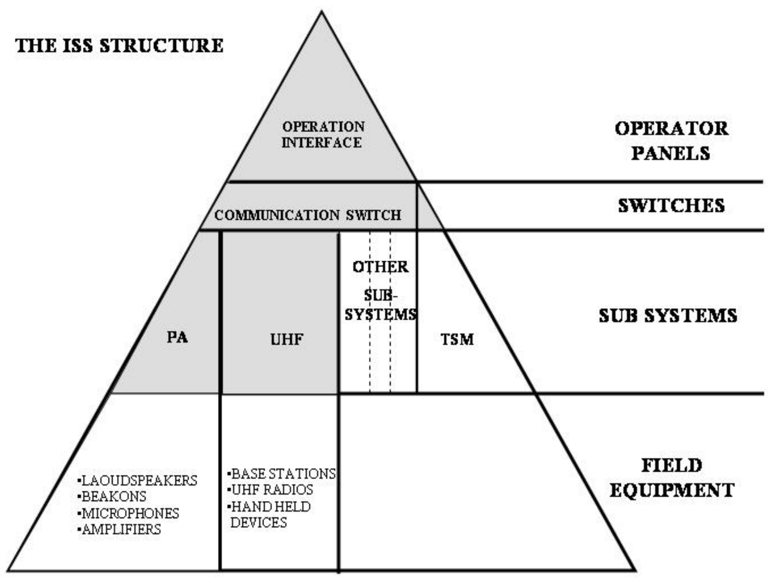

Figure 3-1: System structure

The control panels contain the user interface and the functionality for controlling the entire communication system. Three versions of operator panels shall be available. The communication switches connects the operator panels to the subsystems. It is also responsible for system monitoring. The subsystems are different communication systems or other systems connected to the switches. The workload of this thesis is limited to the integration of the PA system and the UHF system. In addition, the TMS system has been included, which is a common monitoring system for all the subsystems, for the other subsystems to work properly. The three levels are described in details in the following sections. Field equipment is typically loudspeakers, beacons/lights and sensors connected to the subsystems.

To achieve system redundancy and to meet the requirements for offshore safety systems, we had to implement two communication switches. Switch A is the primary switch where all the subsystems are connected. Some subsystems, like the PA-system, require redundancy. These subsystems connect their secondary equipment to communication switch B.

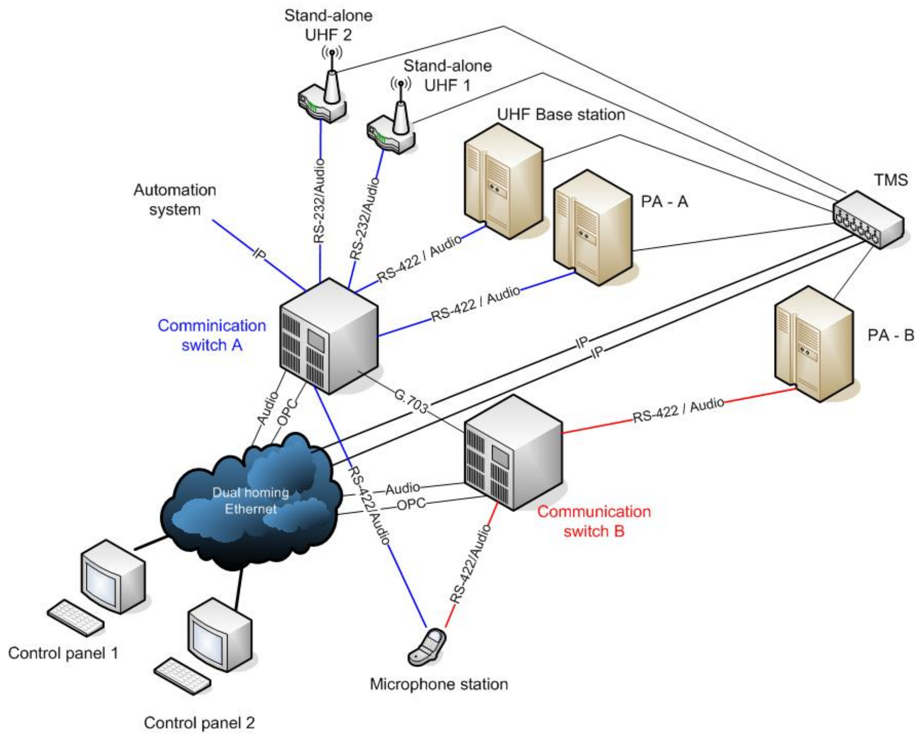

Figure 3-2: The ISS system topology

Since both the PA subsystems shall be used under normal circumstances, the data intended for the PA systems must be transported between the PA - B and communication switch A via switch B. A G.703 link is set up between the switches to handle this functionality. Data received in switch A is transported synchronized to several subsystems in both the switches over the G.703 link. If we send the same data to the two switches over the Ethernet simultaneously, data may not be received in the switches at the same time. This may result in unsynchronized messages on the PA-system. That's why we have decided to communicate with one switch at the time and let the communication switches distribute the data to the right subsystems.

Use of OPC functionality is one the interesting parts of this solution. OPC is mainly used for control and monitoring of automation systems, but we which to implement this into a communication system. The intention is to use OPC for control and monitoring of the communication switches and the subsystems. The communication switches and the TMS got their own build-in OPC servers, but the values from the TMS shall be transferred to the two OPC servers included in the switches. In addition the switch A shall include the tags from switch B and vice versa. This result in both switches includes the same information from all the three OPC servers. The control panels will then have access to information about the entire system no matter what switch they are connected to.

There shall be three different operator panels available; two control panels and one microphone station. The control panels are based on a computer with the necessary equipment and software, where the only difference is the work space. The main solution has a touch screen with a graphical user interface. The second solution is based on existing button panels. Under normal circumstances the control panels communicate with the communication switch A over a dual homing Ethernet [15]. If an error occurs in the switch A or in the connection to the switch, the control panels shall automatically switch over to communication switch B. This shall happen immediately with no loss of data.

3.2 The communication switch

3.2.1 Introduction

The communication switch is the principal component of the Integrated Safety Systems. It performs the switching of data between the connected equipment and includes a complete list of control, status and alarm messages.

The communication switch used in the ISS is based on the switch which is currently under construction by ABB. We have taken the main ideas from this switch and made a proposal for a switch with the right properties for our solution. This section describes the different properties and parts of the communication switch.

The General Functional Design Specification – The communication switch (appendix B) describes the functionality and configuration intended for the switch used in the ISS. The intention of this specification is to provide enough information to make it possible to construct the communication switch. This section provides a technical and functional description of the communication switch.

3.2.2 System structure

The system structure is described in details in the underlying sections. This drawing is a sketch of the communication switch.

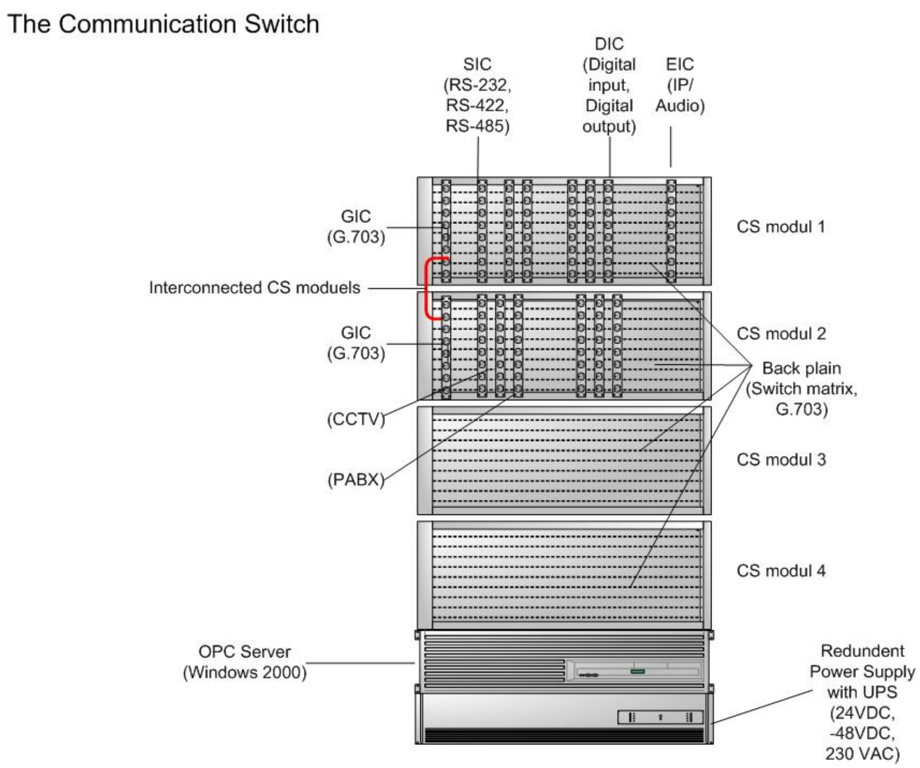

Figure 3-3: The communication switch

The communication switch shall consist of the following main components:

- Communication switch module (CS module)
- OPC server
- Redundant power supply

3.2.3 Functional performance

The main purpose of the communication switch is to switch audio between the control panels and the subsystems. Communication interfaces used by PA systems, UHF systems, TMS systems and other telecommunication systems used on oil installations must be supported by the switch. The CS shall be able to switch audio between a maximum of 120 ports distribute on four CS modules. Each of these CS modules has a maximum capacity of 30 ports.

An OPC server is used for both controlling and monitoring of the communication switch. This OPC server includes OPC points for all necessary information about the switch and connected subsystems.

To prevent downtime, the communication switch shall be equipped with a dual power supply and UPS.

The CS module, the OPC server and the redundant power supply are described in detail in the following sections.

3.2.4 The communication switch module

The communication switch module shall consist of the following main components:

- Interface Card (IC)
- Backplane

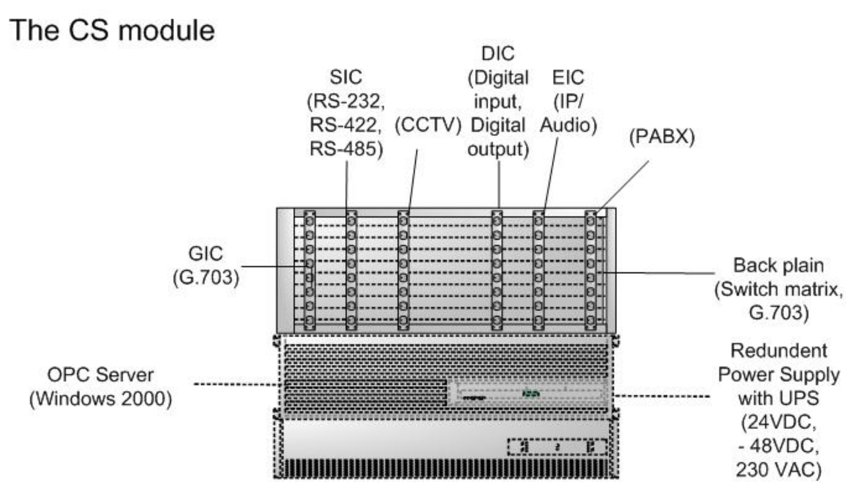

Figure 3-4: The CS Module

The CS module shall support a number of different interface cards. The IC's are used to connect equipment with different communication interfaces to the switch. Since the CS module shall support 30 ports, it must support 30 IC slots. Each of these ports is related to their own time slot in the TDM (Time Division Multiplexing) system. In the switch, audio to and from the different control panels are transmitted in a dedicated time slot.

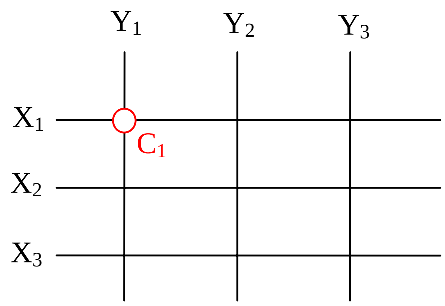

Figure 3-5: Cross matrix

The switching matrix is controlled by points in the OPC server. Every checkpoint in the matrix has its own OPC point. Figure 3-5 is a simplified example of the matrix. Data in time slot 1 (from control panel 1) are transmitted over X_1 and data in time slot 2 (from control panel 2) are transmitted over X_2. If control panel 1 (X_1) wants to communicate with the equipment connected to Y_1, the OPC point belonging to check point C_1 is set in the server by the control panel. The OPC server will then tell the matrix to make a connection at this checkpoint. After the connection at C_1 is made, data may be transmitted from X_1 to Y_1.

3.2.5 The Interface Card

The interface card is one of the two main components of the CS module. The subsystems, the control panels and additional equipment in the ISS shall be connected to different ports on the CS module via various interface cards. The IC shall consist of a printed circuit board constructed to fit into slots on the backplane in the CS module. The IC shall support different electrical interfaces depending on the functionality it shall provide.

The CS shall accept different ICs depending on the functionality intended for the switch. The ICs described in the following section are only suggested solutions to design and functionality. The functionality intended for the most common ICs are described below.

The Serial/audio Interface Card (SIC)
The Equipment Interface Cards are used to connect equipment like the PA subsystem and UHF radios to the communication switch. They shall support two-way audio (Line-in and Line-out) and bi-directional RS-232, RS-422 and RS-485 serial data. Audio is delivered by the switch, while data like selected zones, channels, and alarms are delivered from the OPC server.

The G.703 Interface Card (GIC)
The GIC shall provide the functionality to bypass and exchange data (time slots) with up to four CS modules and other G.703 equipment. It shall also provide the possibility to transmit data on a G.703 link to other G.703 equipment such as radio link systems, PABX systems and other communication switches.

The Digital I/O Interface Card (DIC)
The DIC shall provide a digital interface for input and output connections of digital equipment such as various loudspeakers, beacons etc. The DIC shall also accept input from the SAS (Safety and Automation System). The DIC shall be used to select UHF channels.

The Ethernet Interface Card (EIC)
The EIC shall decode audio received from the control panels and forward this data on to the switch matrix in the CS module. In addition the EIC shall encode audio from the switch matrix, and forward this data to the Ethernet. Ordinary Ethernet functionality shall also be supported. TCP/IP shall be used for communication between the control panels and the communication switches. TCP/IP is used to ensure reliable data delivery.

Other ICs
As already stated in a previous section the communication switch shall accept interfaces used for PA systems, UHF systems, TMS systems and other telecommunication systems used on oil installations. Therefore the CS module shall accept ICs of other telecom systems such as PABX and other equipment not suitable for the described interface cards.

3.2.6 The Backplane

The backplane is the other main component of the CS module. The interface cards shall be connected to slots on the backplane. The main component of the backplane is the switch matrix (SM). The SM shall be able to receive and forward 2048 kbit time frames. Each timeframe consist of 32 different timeslots of 64 kbit each. The first time slot of the 2Mbit time frame is normally used for synchronization, and the 16^{th} time slot is normally used for signaling. The 30 remaining time slots are used to exchange data between the different equipment connected to the CS module. It shall be possible to switch between every port in the SM. The OPC server shall be able to monitor and control the status of the SM. The functionality of the OPC server is described in the following section.

3.2.7 The OPC server

OPC
OPC, or OLE (Object Linking and Embedding) for Process Control, is a published industrial communication standard for system interconnectivity or exchange of process and control data [14]. OPC uses Microsoft COM (Component Object Model) and DCOM (Distributed Component Object Model) technologies to enable applications to exchange data on one or more computers using client to server architecture. OPC provides single value data items called points. Each point includes a value, a quality and a time stamp.

New usage for the OPC technology
The intention is to use the OPC technology to control the entire ISS system using OPC server client architecture. As far as we know, this introduces a new usage for the OPC technology.

The idea is to include an OPC client in each control panel and to include OPC servers in each communication switch. The TMS system shall also be equipped with an OPC server. The OPC server in a CS shall include all the OPC points from the TMS system and other connected communication switches. The control panels (OPC clients) shall be given access to these data through OPC connections over the Ethernet. This way the control panels are able to monitor changes to the ISS indicated by changes to the value of the different OPC points. The ISS shall be able to respond to these changes according to predefined configuration settings. As an example, there might be a small fire in the drilling area on the installation. A smoke detector connected to the automation system detects smoke and generates a signal to the PA system. The PA system responds to this signal by setting an alarm and generating a new signal to the TMS system. The TMS system changes the values of the OPC points related to the received signal. Since each OPC point in the TMS system also is represented in each CS, the related OPC point is changed. The control panels continuously monitor the OPC points on the OPC server. When changes to the OPC points related to the alarm occur, the operator is notified by flashing pushbuttons or touch screen buttons on the control panels.

Functional Performance
To provide OPC functionality, the different equipment must run Windows 2000 or similar software supporting OPC.

Each communication switch shall be equipped with an OPC server. OPC clients, such as the control panels and various controllers, exchange the single value data items called points with the OPC server.

The OPC server shall be used for monitoring and surveillance of the switch matrix. As an example, an operator may be using a specific UHF channel on the UHF system for communication with the maintenance crew. Since an OPC client is installed in each operator panels, the other operators can be notified indicated a busy light on the operator panel.

The ISS shall be controlled based the values in the OPC server. The OPC server shall include a complete list of OPC points for system control and monitoring. This list shall consist of various OPC point such as check points for the switch matrix, connection statuses, and selection of PA zones and UHF channels. It shall be possible to control the entire ISS by changing the OPC points from the control panels. As an example, one check points in the switch matrix are controlled by changing a related OPC points from one value to another. If the operator whishes to select a different zone on the PA system, the OPC point related to this zone is set from the control panel.

Another functionality the OPC server shall provide is to notify the ISS of process alarms and events by setting different OPC points to predefined values. If an alarm or event is of a more serious type, the operator shall be notified by changes to the user interface on the operator panel. The changes made to the user interface depend on the configuration of the ISS. The intention of this functionality is to help the operators in critical or in emergency situations. Depending on the type of alarm or event received, the user interface shall provide the operator with all the necessary functionality to operate the system under such conditions.

The OPC server shall also provide the possibility to exchange data with other OPC servers. If each CS in the ISS provides OPC server functionality it becomes possible for one OPC server to monitor a number of other OPC servers. The intention is to use this functionality to monitor the ISS. If one of the communication switches becomes dysfunctional, the monitoring OPC server will become aware of this and switch data through the other CS.

3.2.8 Power supply

The CS shall be equipped with two separate power supplies. Each power supply shall be able to supply the entire switch and the connected microphone stations in case one of the power supplies fails. Each power supply shall be equipped with UPS and power failure indicators. If one of the power supplies fails, the power failure indicator shall notify the OPC server by setting an OPC point and the other power supply shall take over with no breaks (hot standby). It shall be possible to change power supply on live equipment without affecting the operation of the switch.

The CS shall accept the following redundant power supply combinations:

- 24 VDC and 24 VDC
- -48 VDC and -48 VDC
- 230 VAC and 230 VAC
- 24 VDC and 230 VAC
- -48 VDC and 230 VAC

3.2.9 Redundancy

To provide redundancy the ISS shall be equipped with two communication switches, CS-A and CS-B. Equipment requiring redundancy, such as the PA system, shall connect one of the equipment to each switch. Equipment not requiring redundancy shall be connected to the CS-A. If a failure is detected on the CS-A, the CS-B shall become responsible for the switching of data between the control panels, the subsystems and the additional equipment connected to the switches.

3.2.10 Switching Criteria

The control panels shall use the quality value of the OPC points to monitor the TCP/IP connections to the switches, the G.703 connection between the switches and the status of the switches. This is possible since both switches include each others OPC points. Table 3-1 shows how to find status for the connections and the switches.

Table 3-1: OPC point monitoring

		OPC points from server 1 in server 2	
		Very good	Bad
OPC points from server 1 in server 1	Very good	Ok connections	G.703 link failed
	Bad	IP connection 1 failed	Switch 1 failed

		OPC points from server 2 in server 1	
		Very good	Bad
OPC points from server 2 in server 2	Very good	Ok connections	G.703 link failed
	Bad	IP connection 2 failed	Switch 2 failed

Under normal conditions the control panels shall communicate with the subsystems through the CS-A connection. If a failure to the TCP/IP connection between the control panel and the CS-A occur, the control panel shall automatically switch all communication to the CS-B connection. The OPC servers in the CS-A and CS-B shall then be notified about the failure, and data shall be rerouted from the CS-A through the CS-B via the G.703 link. The control panels can then receive these data via the CS-B connection. A failure to the G.703 link will cause the CS-A and the CS-B to loose synchronization with each other. Besides, subsystems connected to CS-B will be unavailable. Although, the control panels shall not send data to both communication switches simultaneous. This will cause interference of voice intended for the PA systems.

3.2.11 Fault Detection

The communication switch shall be able to detect various faults in the CS modules, interface cards and power supplies. If possible, the switch shall also monitor all connected connections and the system temperature. The OPC server shall include OPC points for each of these values. All operators shall be informed about any critical failure in the communication switch.

3.3 The Subsystems

The subsystems are different types of telecommunication and monitoring systems connected to the communication switches. It shall be possible to connect several different subsystems to the system, even existing subsystems. This thesis only describes how the PA subsystem, the UHF subsystem and the TMS subsystem are integrated in the ISS, its general performance and functions.

Integrating several subsystems to one common system will result in a more complete solution. This integrated solution shall be controlled from one common control panel. Besides, the ISS can collect alarms and status messages from the different subsystems. The system can then use these messages to inform the operators, set alarms and configure the system and the control panels to best suit critical situations.

The subsystems will be placed in different equipment rooms on different locations on the installation to avoid loss of all the equipment in an explosion, fire, etc. The equipment rooms are safe areas so the subsystems do not need to be EX certified or meet any other environment restrictions.

The subsystems will have different requirements to the power supply. This will vary from vendor to vendor, but all subsystems must meet the requirements in the NORSOK standard. It is recommended to use dual power supply and UPS. For new subsystems we require dual power supply and UPS.

The subsystems shall use one of these voltages:

- 24V DC
- -48V DC
- 230V AC

Dual powered subsystems may have two power supplies with the same input voltage or two power supplies with different input voltage, except the combination of 24 VDC and –48 VDC.

3.3.1 PA system

The PA system is an emergency system. According to the NORSOK standard [1], it shall *“distribute alarm tones, emergency messages and routine messages to different areas of the installation. In areas with a high acoustical level alarm yellow flashing lights shall complement tones and emergency messages”*.

Since the PA system requires redundancy, there must be two PA subsystems included in each solution. One subsystem shall be connected to each communication switch. Both PA subsystems shall be used simultaneously. The PA subsystems are connected to its own set of field equipment like loudspeakers and beacons. Under normal conditions all these equipment shall be operational. The PA subsystems have connections to the F & G system, the entertainment system, the PABX and the UHF system.

The PA subsystems shall provide the TMS with alarm and status messages. The following messages must at least be available from the PA system.

- Audio connection status
- Data connection status
- Overheating
- Amplifier status
- Power status

3.3.2 UHF system

In the ISS there are two types of UHF subsystems, UHF base stations and stand-alone UHF radios. The UHF base stations are UHF radios with one predefined duplex channel. The UHF base stations cannot be used with any simplex channels. Several UHF base stations are gathered in the UHF base station subsystem. To use simplex channels, the operators have to use a stand-alone UHF radio. This stand-alone UHF radio can also operate on duplex channels. To achieve full flexibility for the operator, there must be one dedicated stand-alone UHF radio per control panel.

The UHF base station subsystem shall provide alarm and status messages to the TMS. The following messages must at least be available from the UHF base station subsystem:

- Audio connection status
- Data connection status
- Power status
- Overheating

The UHF stand-alone radios shall handle all the simplex and duplex channels legal for maritime use. These radios must have functionality for remote operation and configuration. It shall be possible to perform the following operations from a remote control panel:

- Send and receive audio
- PTT
- Choose channels

The UHF stand-alone radios shall at least provide the following status messages to the TMS:

- Audio connection status
- Data connection status
- Power status

3.3.3 TMS-system

The TMS collects alarm and status information from all the subsystems. This information shall be accessible from a built-in OPC-server and will be used by the ISS to set up the communication switches, control panels, to set alarms and to give the operators different status messages. The TMS shall be connected to the Ethernet with two different connections to ensure redundancy.

3.4 The operator panels

Currently, all the different subsystems have their own control panel and wiring. This results in a lot of equipment in the control rooms and wiring around the installation. Besides, the different control panels often have more or less the same functionality, buttons and layout. In the ISS all the control panels shall be able to control all the different subsystems, and all communication shall be transported over a common network. This will result in less equipment and cabling, and the operators will only have one control panel to deal with.

The ISS includes three types of operator panels. There are two control panels, one with a graphical touch screen interface and one with a button panel interface, and one microphone station. The two control panels are principally equal, both equipped with a computer with the necessary hardware and software. Only the workspace is different. On the touch screen version a graphical user interface will dynamically change depending on the operator's choice and incoming status and alarm messages. The touch screen solution is the primary solution, but a button panel solution is also available. This solution use existing button panels connected to the control panel computer. The button panels may not change layout, but the settings on the panels shall dynamically change according to settings in the OPC servers. This solution makes use of existing microphone stations. These stations are not connected to the common Ethernet, but have one separate serial connection to each communication switch. The microphone stations are emergency stations located on strategically locations on the installation. They consist of one microphone and one PTT button, and are only capable of sending voice messages to the PA system.

The control panels shall be able to receive status and alarm messages from the subsystems and the communication switches. Based on these messages the user interface and functionality shall dynamically change to best suit the new situation, and the right equipments at the right areas shall automatically be selected. This may reduce the time before alarms and messages are given and reduce the chance of human mistakes.

All the operator panels have to be connected to both the communication switches to fulfill the requirement of no single failure. If one connection fails, another route to the equipment is still maintained.

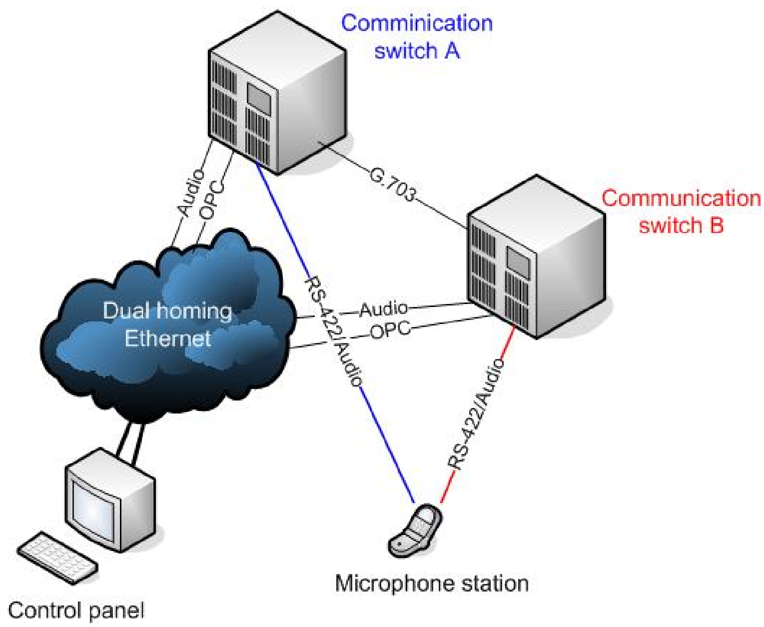

Figure 3-6: Control panel and microphone station

The number of control panels may vary from installation to installation. There must be at least one control panel in the system, and the maximum number of control panels is limited by the number of free ports in the communication switch.

3.4.1 Control panels

A control panel is based on a computer with control software, a microphone, a loudspeaker, a soundcard, and two Ethernet adapters. Data to the different subsystems shall be transmitted over one common dual homing Ethernet. To handle signals from the PTT-button and the pushbutton panels, the control panels must have a number of serial ports. They shall also have one microphone (Line-in) and two loudspeakers (Line-out) audio interface.

There shall be two different user interfaces available for the control panels, either a touch screen with a graphical user interface (GUI) or a button panel user interface. On a touch screen the GUI shall dynamically change according to the operator's actions, status messages and alarm messages. Since the pushbutton panels are based on existing panels, the control panel has to support these pushbutton panels. For more information about the user interfaces, see chapter 4.

At startup the control panels shall set up two TCP/IP connections to both the communication switch A and the communication switch B over the redundant Ethernet. The control panels shall connect to switch A with one of the Ethernet interfaces, and to switch B with the other Ethernet interface. As long as the communication switch A and the belonging connection is operational, this is the active connection and the connection B is a hot standby connection. Data from the communication switch B shall be available all the time, but disregarded as long as the communication switch A or the connection A is operational. If the communication switch A or the connection A fails, the control panel shall switch all communication over to connection B immediately. The control panels also have to connect to the OPC server in the two communication switches at startup. These OPC servers give the control panels the necessary information about the entire ISS and are absolutely necessary for the system to work properly. By reading OPC points, the control panels receive status and alarm messages such as detecting equipment use by other operators. This information is used to set up the control panels and to inform the operator about various events. If the ISS receives an alarm message from the F & G system, the F & G alarm in the PA system shall automatically be set.

The control panels also use the OPC servers to set up the connection through the communication switches and to configure the subsystems. Values for the selected equipment, channels, zones, alarms, etc shall be written to the OPC server.

The control panels will be placed in different control rooms in various locations on the installation. The control panels will be placed indoor, so there are no special environment restrictions for this equipment.

The control panels consist of different parts, such as a motherboard, CPU, power supply, workspace and Ethernet adapters. If one or more of these parts fail it is possible to repair or change these parts. There is no need to change the whole control panel unless it is exposed to a larger amount of damage.

To avoid downtime the control panels shall be provided with two power supplies and an UPS. The power supplies must support one of the following input voltages:

- 24 VDC
- -48 VDC
- 230 VAC

The control panels may have two power supplies with the same input voltage or two power supplies with different input voltage, except the combination of 24 VDC and –48 VDC.

3.4.2 Microphone stations

The microphone station (MS) is a unit for emergency use only. It consists of one PTT button and a microphone, and is only capable of sending voice messages to the PA system.

The MS is hardwired to each communication switch by a RS-422 connection and an audio connection. The connection transmits data, audio and power, so the microphone stations do not need its own power supply.

The microphone station will be located on different critical areas on the platform. Even the control rooms may have an MS. If the power supply fail in one of the control rooms, and all other control panels are useless, the operator will still have the possibility to give messages on the PA system. The microphone stations may be placed outdoor, so they have to meet various restrictions for outdoor equipment.

3.5 Summary

This chapter is a detailed documentation of the three main levels of the ISS. As the Figure 3-1 describes, the ISS is divided into three main levels, the operator panels, the communication switch and the subsystems. First the functionality and structure of the communication switch and its components are described in detail. Second the functionality of the OPC server is explained. Then the functionality of the subsystems (PA, UHF, and TMS) is described. At the end of this chapter the structure of the different operator panels are described in detail. The next chapter describes the design and functionality of these different operator panels.

4 Design and functionality of the operator panels

4.1 Introduction

The Integrated Safety System includes three different operator panels, a control panel with a touch screen user interface, a control panel with a pushbutton panel user interface and a microphone station.

The vision is to have one common user interface for all the different subsystems. In this project we shall concentrate on the integration of the user interfaces for the PA system and the UHF system. Currently, the operators have to use two different pushbutton control panels when operating the PA system and the UHF system.

Our original idea was to make a user interface providing the exact same functionality for both the touch screen control panels and the pushbutton control panels. In addition, this user interface should be able to dynamically change functionality according to various system conditions. We discovered that making a pushbutton panel capable of dynamically changing functionality and layout is more complicated then we first predicted, especially since the idea is to gradually integrate even more telecom system into the solution. We therefore decided to use existing pushbutton control panels. But instead of using serial RS interfaces, normally used today, these control panels shall be connected to a computer connected to the Ethernet. This computer is the same as used for the touch screen panels.

In addition to the pushbutton control panels, we have made a proposal to an integrated user interface for the PA system and the UHF system used on touch screen control panels. Because we had no experience in use of such systems, our supervisors directed us to find elements for improvements until we had a satisfying proposal.

This section provides a detailed technical documentation on the design and the functionality intended for the different operator panels used in the Integrated Safety System.

4.2 Touch screen panels

We have made a proposal to a graphical user interface for a touch screen. The intention is to make a graphical user interface which is easy to use and understand in both normal and critical situations. Colors are used to indicate different status levels. Red indicates alarm/danger, yellow indicates busy/attention and green indicates ok/on and gray indicates off/idle.

The graphical user interface is divided into several displays. There is one main display, one display for the PA system and one for the UHF system. When new subsystems are connected, new displays will be added to the graphical user interface.

4.2.1 Main graphical user interface

The main display (Figure 4-1) contains an overview of the entire ISS. It shall give the operator visual information about the most important statuses of the system. Most of the screen will present a process-monitoring picture located to the right. To the left there will be a collection of the most important information about the ISS divided in sections. Under the process overview picture there will be a text area where the most recent alarms and messages are listed with the date and time they occurred.

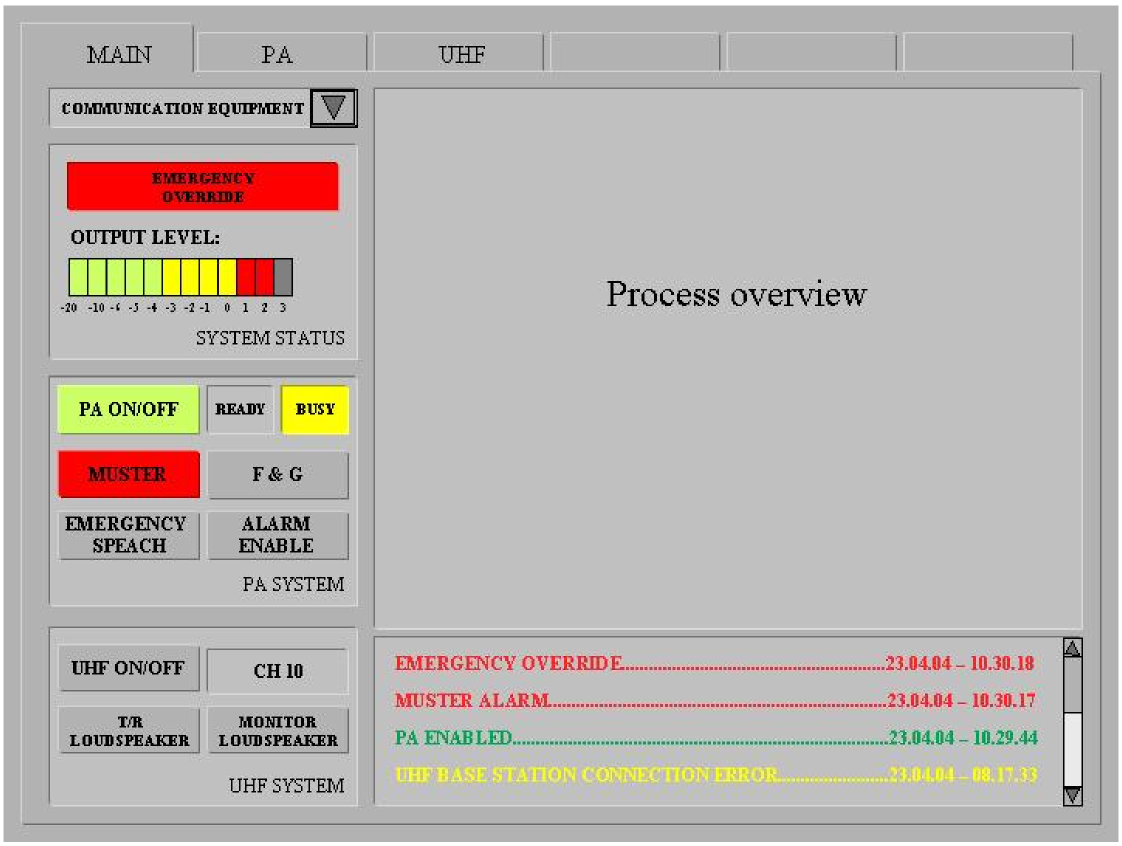

Figure 4-1: Main graphical user interface

The upper communication equipment button is used to show or hide the information sections below. Hiding these fields will give the operator a larger process overview. If any alarm occurs, the information sections shall automatically appear.

In the system status section the emergency override lamp tells the operator that the system is overriding his/her current settings. This lamp flicker red when activated. This section also contains a microphone output level indicator.

In the PA section there are five buttons and two lamps. The PA on/off button is used to enable and disable the PA system. If the PA system is enabled, all the audio from the microphone will be sent to the PA system. If it is disabled no audio is sent. The muster, F & G and emergency speech buttons are used to set the belonging alarms. To set an alarm the operator first has to push the alarm enable button. The alarm buttons are gray when no alarms are set and flashing red when the alarms are set. The alarm enable button is gray, but turns yellow while pushed. A yellow busy light indicates that the PA system is in use by another operator. Then it is not possible to access the PA system. If the busy lamp is gray the PA system is free to use. The ready lamp is gray when the system is idle. When the operator makes a connection to the PA system, the lamp flashes green. The lamp turns stable green when the connection is established and the system is ready to send messages.

The UHF section has three buttons and one display. The UHF on/off button enables and disables the belonging UHF systems. The channel display indicates what channel the UHF system is operating on. The T/R loudspeaker and monitor loudspeaker buttons are yellow if the belonging loudspeaker is muted, and green if it is not muted. These buttons shall flicker when audio is sent on the monitored channels even when the loudspeakers are muted.

The process overview includes a sketch of the process system. This sketch shall graphically present system status for the operator. Any system fault and where the fault is located shall be shown here.

The text area shall list the most recent error and system status messages. The messages shall have different levels of importance. These levels shall be indicated by different text color. Red text color indicates critical messages, yellow indicates important messages where the operator has to pay attention, and green indicates none-critical messages and general information.

4.2.2 PA graphical user interface

The graphical user interface of the PA system contains information about alarms, system status, output level, and zone selection (Figure 4-2).

The PA system is divided into zones. From the control panel the operator shall be able to select various PA zones. The different zones on the installation are marked with different colors on a sketch on the control panels, so it shall be easy to select the right zones.

The operator shall also be able to set different alarm messages in the alarm section. To do this, the operator first has to push the alarm enable button, to prevent alarms set by accident. To turn off the alarm, the operator has to push the cancel alarm button. These buttons are gray, but turns yellow while pushed. The alarms may be trigged in two ways, manually by the operator or automatically by a system emergency message. The alarm buttons are flashing red if the alarm is trigged. If an alarm is automatically set, the system shall act according to predefined settings and the GUI shall switch to the main display. Depending on the alarm received particular PA zones and UHF channels shall be set.

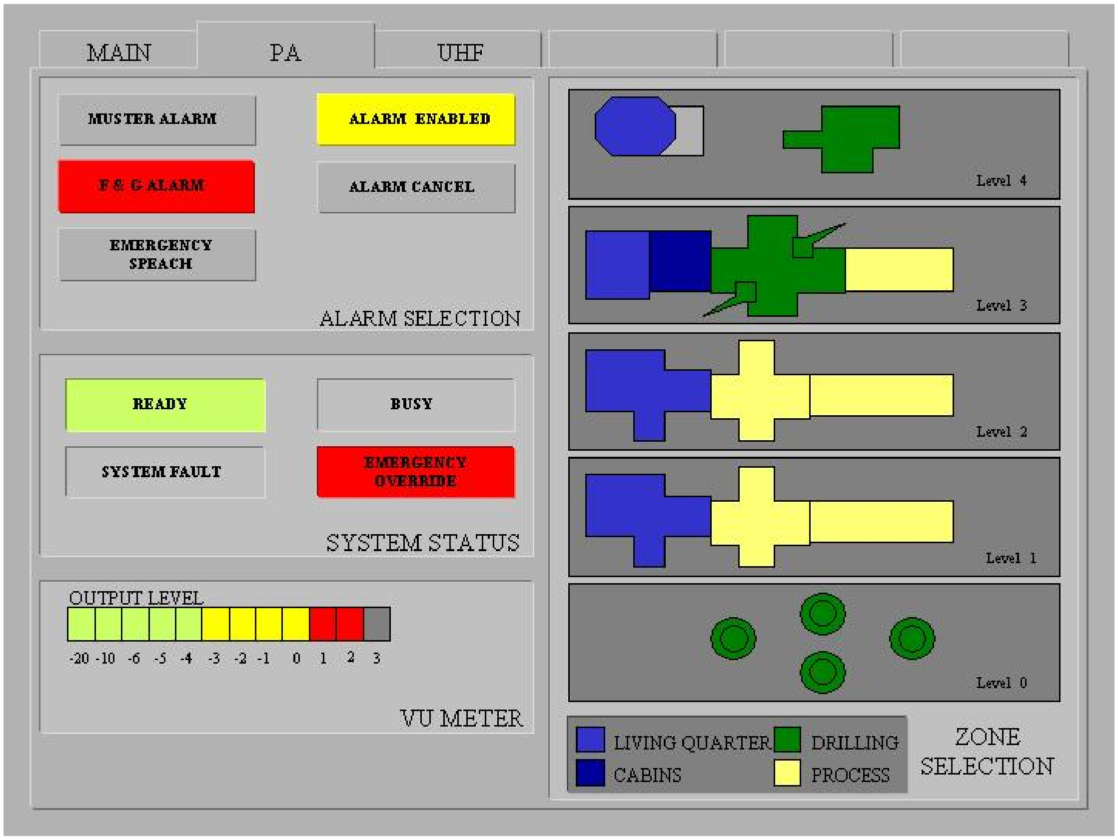

Figure 4-2: PA graphical user interface

The PA interface also includes some system status indicators. The ready light is flashing green when the control panel is connecting to the PA system and it turns stable green when the connection is established. The lamp is gray in idle mode. The busy lamp is yellow when the PA system is in use by another operator, and is gray when the PA system is idle. The system fault light goes from gray to red if there is something wrong in the system. Emergency override tells the operator that the system is overriding her/his setting. The lamp turns from gray to red in this situation.

4.2.3 UHF graphical user interface

The UHF graphical user interface is used for operating both the UHF base stations and the UHF stand-alone radios and contains functionality for selecting UHF channels, loudspeaker muting, and a list of channels with description and frequencies.

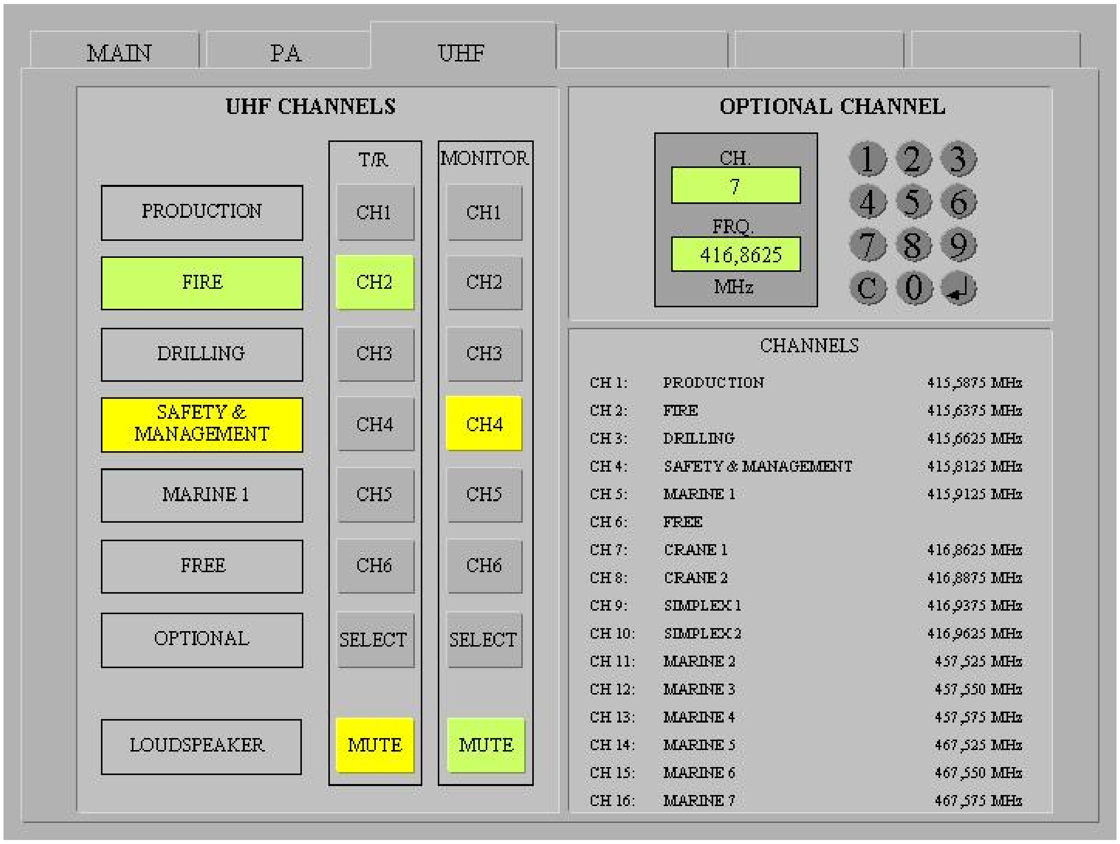

Figure 4-3: UHF graphical user interface

UHF base stations have predefined channels marked as CH1 – CH6 in the T/R (transmit/receive) and monitor sections with a description label to the left. Since there is just possible to use one UHF stand-alone radio channel at the time, there is only one button in each T/R and monitoring section for this purpose. This is the optional channel. An optional channel may be selected by pressing the select button, enter the wanted channel in the numerical keyboard, and finally press the enter key. The buttons in the T/R column are used to select channels for ordinary radio communication. The selected buttons and belonging labels turns green, and start flashing when data are sent or received on the related channel. The operator will only have the possibility to use one of the predefined channels at the time, but may use the optional channel simultaneously. The buttons in the monitor column are used to select channels to monitor. It shall be possible for the operator to monitor several channels at the time, both the predefined and the optional channels, but not a channel already selected in the T/R column. The selected buttons and belonging labels turns yellow, and start flashing when data are sent and received on the related channel.

Audio on channels used for T/R and monitoring are separated on two different loudspeakers. It shall be possible to mute both loudspeakers separately. The mute buttons are yellow when muted and green when not muted.

The UHF graphical user interface also includes a list of predefined channels. This list gives a description of the different channels and their exact frequency.

4.2.4 Connection alarm interface

If the control panel looses the connection to both the communication switches, the operator shall be informed immediately. We have indicated this by using a red background color in the graphical user interface. Figure 4-4 is an example from the PA interface.

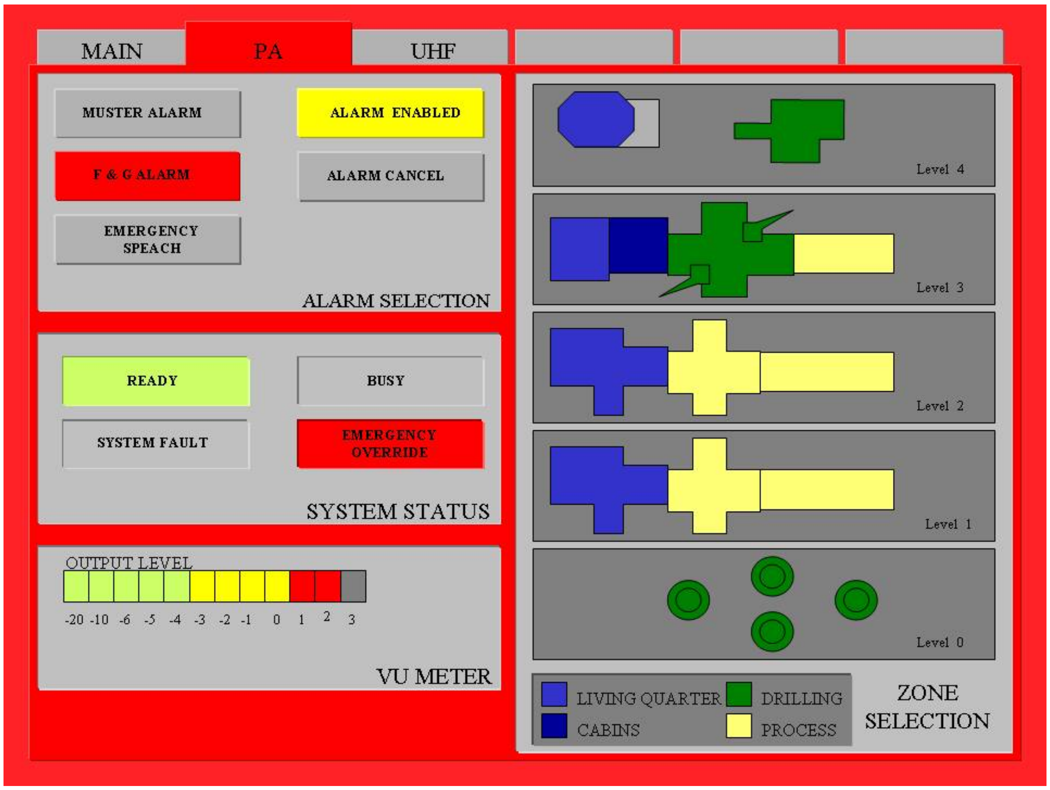

Figure 4-4: Connection alarm interface

4.3 Pushbutton panels

The button panels are based on existing panels. These panels are standard 19" rack for desk montage. Instead of connecting the panels directly to the subsystems over a serial connection, the panels are connected to the control panel computer. We will need one of these button panels for each subsystem. Figure 4-5 is an example of a PA-panel from Phontech.

Instead of having one or two microphones, a PTT button, and an output level indicator on every button panel, one common microphone, PTT button, and output level indicator will be located on a separate panel.

The NORSOK standard defines mandatory buttons which shall be included on each subsystem control panel. Vendors of such panels have to comply with these requirements. The control software in the control panels must support the selected button panels. Making different software modules for each button panel makes it easy to implement new button panels and subsystems to the control software.

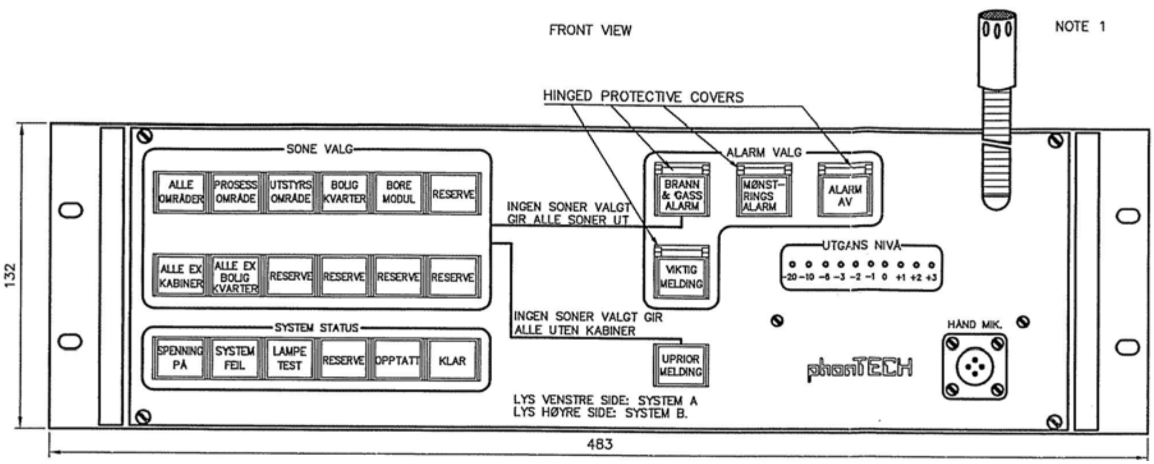

Figure 4-5: PA control panel from Phontech

4.4 Microphone stations

We have decided to use ordinary microphones station in the ISS. The microphone stations consist of one microphone and one a PTT-button. Figure 4-6 is an example of a microphone station developed by Phontech.

By pushing the PTT button, voice messages will be broadcasted to all zones on the PA system.

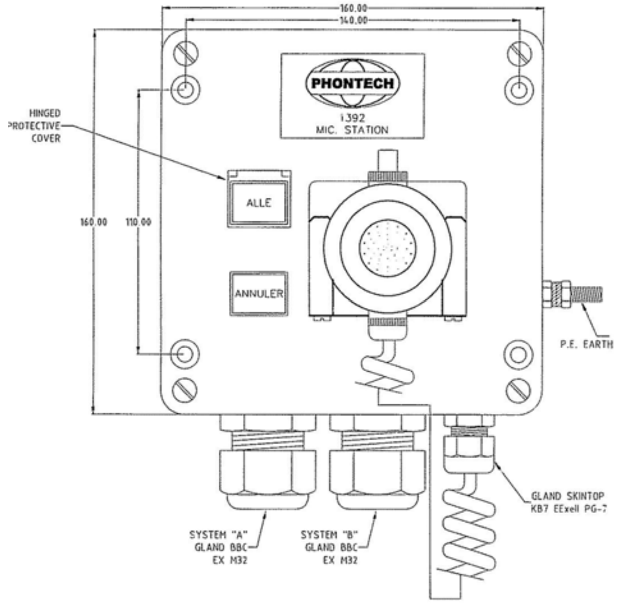

Figure 4-6: Microphone station

4.5 Summary

This chapter describes the user interface for two control panels, touch screen and button panel, and the microphone station. The touch screen has a graphical user interface where the display dynamically changes according to incoming status messages. The interface on the button panels are based on existing panels and are therefore unable to change layout, but the settings will change according to incoming messages. The microphone stations consist of one microphone and a PTT button and have no functionality beyond sending voice messages to the PA-system.

5 General functional design specifications outline

5.1 Introduction

One part of this thesis has been to write proposals on detailed functional design specifications or new revisions of existing specifications for the Integrated Safety System based on the selected transportation solution.

We have developed the ISS from scratch. Since the ISS is not developed on existing solutions we have also written the proposals on the detailed functional design specifications from scratch. We had no experience with writing functional design specifications and we had no experience with the PA system and the UHF system, which our solution is based on. The development of these specifications has been one of the most demanding processes of this thesis.

To receive knowledge on the PA system, the UHF system, the TMS system and additional equipment related to these systems, we have studied the NORSOK T-100 standard and various specification at ABB. Our supervisors and other employees at ABB have also contributed to increase our knowledge on these systems.

The specifications have been designed according to a template normally used by ABB. We have also studied various specifications to get an idea of how to construct a specification.

The contents of these specifications have changed continuously in parallel with the development of the ISS and as we gained more knowledge on the different issues described in these specifications. In addition, these specifications have repeatedly been evaluated by our supervisors at ABB, and we have made changes to the specifications according to the feedback received from our supervisors.

5.2 The structure of the specifications

The structure of the ISS is divided into the three following sublevels:

- The operator panels
- The communication switch
- The subsystems

We decided to write four proposals to functional design specification, a general specification describing the functionality intended for the entire ISS, and three detailed specifications describing in detail the functionality intended for each of the different sublevels. There might be some minor misconception between the specifications and the information provided in this report. The reason for this is that we ended the work on the specifications before we have finished the work on this report. This means that the information provided in this report is more up to date then the information provided in the specifications. The writing of these specifications has resulted in the following four proposals to functional design specifications:

- General Functional Design Specification – The Integrated Safety System
- General Functional Design Specification – The control panels
- General Functional Design Specification – The communication switch
- General Functional Design Specification – The subsystems

The General Functional Design Specification – The Integrated Safety System provides a brief overview of the functionality, structure and topology intended for the ISS.

The General Functional Design Specification – The control panels is a detailed description of the functionality intended for the different operator panels used in the ISS. In addition this specification describes the design and layout we have suggested for these panels. The following panels are described in detail in this specification:

- The touch screen panel
- The pushbutton panel
- The microphone station

The General Functional Design Specification – The communication switch provides a detailed documentation on the functionality of the switch and the functionality intended for the different components in the switch. This specification describes in detail the functionality intended for the following main components of the communication switch:

- The CS module
- The OPC server
- The power supply

The General Functional Design Specification – The subsystems describes the functionality intended for the subsystems included in the ISS. The following subsystems are currently included in the ISS:

- The PA system
- The UHF system
- The TMS system

5.3 Summary

The previous chapters in this report have described various parts of our solution. One part of this thesis has been to write proposals on functional design specifications based on the results presented in the previous chapters. This chapter has provided a short description on the design and structure of the four different specifications we have written. The general functional design specifications described in this chapter are included as appendix A - D.

6 Demonstrator

6.1 Introduction

If there was enough time left at the end of the project we should develop a demonstrator for the selected solution. The intention of the demonstrator was to test the reliability and the functionality in the solution. Besides we wanted to find out if the solution would fulfill the requirements to such a safety system. This demonstrator should consist of a test version of the integrated user interface and the selected transportation technology. Unfortunately we did not have enough time at the end of the project to develop this demonstrator, but we started early on the preparation for the development of the demonstrator. The writing of the functional design specification was more time consuming and demanding then we first predicted. We therefore decided to keep focus on the specifications and make them as satisfying as possible since this is one of the main tasks of this thesis. This section describes the preparation process of the development of the demonstrator.

6.2 OPC

The idea to use an OPC server and OPC client architecture to control the ISS was developed thorough numerous discussions with our supervisors and other employees at ABB. As we already have mentioned this is a new user area of the OPC technology as far as we know. One of the user areas where ABB normally have used the OPC technology is for communication between various controllers and different automation systems.

We had no experience with OPC when we first started with the master thesis. To gain knowledge on this subject we have used various OPC tutorials [3] on the internet. In addition the personal at ABB have contributed to increase or knowledge on OPC.

6.2.1 Matrikon OPC tutorial

As a starting point we used Matrikon's Introduction to OPC Tutorial [16] to get a brief overview on OPC. The following network design diagram figure and its explanations are taken from the OPC tutorial.

The Network Design Diagram, shown in Figure 6-1, outlines how the software applications connect with one another.
• Each box denotes a separate software application
• Each line denotes a connection

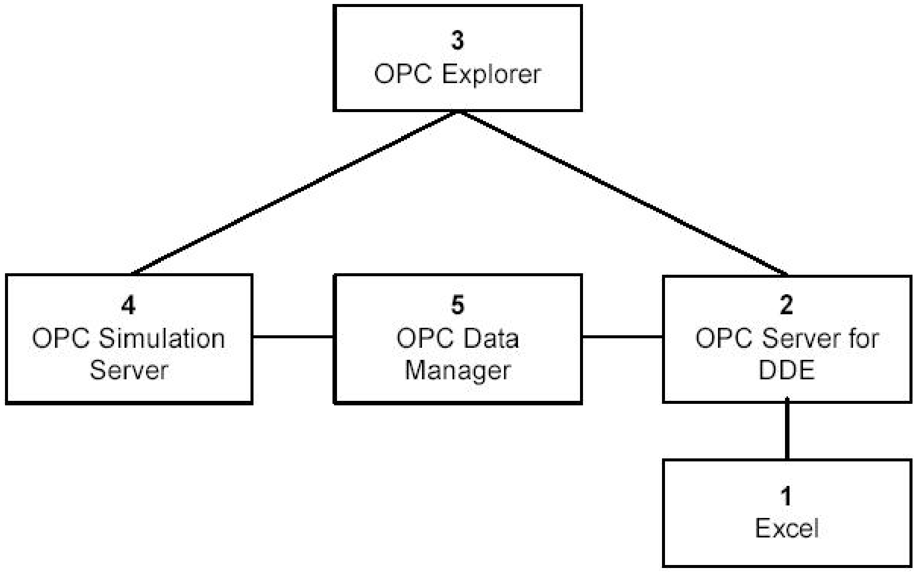

Figure 6-1: The Network design diagram.

In Figure 6-1, the process control system is arranged as follows:

*1. **Microsoft Excel** acts as the data source. All of the process control data is read from and written to **Microsoft Excel**.*

*2. The **OPC Server for DDE** connects **Microsoft Excel** to the OPC client.*

*3. **OPC Explorer** acts as the data sink. It reads data and commands, and writes data back to **Microsoft Excel**.*

*4. The **OPC Simulation Server** connects to a sample device or sample application. It transfers random data that will be read by **OPC Explorer.***

*5. **OPC Data Manager** connects the two OPC servers. Sample tag values are be shared between these two servers.*

First we installed the OPC Server for DDE, the OPC Explorer, the OPC Simulation Server and OPC Data Manager on our computers. Then we made an Excel sheet containing three data values as explained in the tutorial. We then established a connection between the OPC Server for DDE and the Excel sheet. When this connection was established we configured the OPC Explorer to read and write the data values in the Excel sheet using the DDE Server. We had now created our first OPC server and OPC client architecture. The OPC server (OPC Server for DDE), provides the OPC client (OPC Explorer), with the possibility to read and write data to a data source (Excel).

The final steps of the tutorial are to connect the OPC Simulation Server to the OPC Severer for DDE via the OPC Data Manager. This shows how to connect several OPC servers and how to exchange data between them without having to go through an OPC client. It also shows how an OPC client can connect to several OPC servers and read and write data to a data source using several connections.

6.2.2 OPC server development

We decided to develop an OPC server using the Delphi programming language. The reason for this was because the employees at ABB had most experience with writing OPC using Delphi. They recommended us to use Delphi because Delphi is probably a more suitable language for development of OPC software compared to other programming languages.

Because we had no experience with Delphi we used Borland Delphi Quick Start [17] and Borland Delphi Developer's Guide [18] in addition to various tutorials on the internet to receive more knowledge on this subject.

First we made small COM objects such as various “Hello world” applications (appendix F), an application with one button generating a “Hello world” message when clicked, testing various ActiveX objects. We made these simple applications to learn more of how to program in Delphi.

The next stage was to develop an OPC server and connect the Matrikon Explorer (OPC client). The intention was to see if we were able to exchange data between the OPC server and the OPC client. One of the employees at ABB provided us with a demo version of an OPC server, Demo Data Access Server 2.0 (appendix F), developed by Gerhard Schmid at Achat Solution, Germany [19]. This OPC server includes the same functions we had to develop for our OPC server. The functions of interest were the OnRead, the OnWrite and the OnInitAddressSpace included in the uOPCDemo file of the Demo Data Access Server 2.0 application. We have reused the OnRead and the OnWrite functions of the demo server application, and we have made modifications to the OnInitAddressSpace function. The intention of the modifications we made to the OnInitAddressSpace function was to test our own OPC server with Matrikon's OPC Explorer. We created some test data (Static, Computer Name, User Name, Dynamic and Time) the same way we created the data values included in the Excel sheet described in the previous section. We then established a connection between our OPC server and the relating data values of Matrikon's OPC Explorer. We were able to exchange data between our OPC server and Matrikon's OPC Explorer as we had hoped.

6.3 Summary

This section has described the preparation work for the demonstrator. Unfortunately we were unable to do any further development of the demonstrator. One of the reasons why we did not have enough time for the development of the demonstrator was because of the extra time we used on the functional design specifications. Even though we did not finish the demonstrator, we have learned a lot from this process. First of all we have increased our knowledge on OPC. We made a demo version of an

OPC server capable of exchanging data with an OPC client (in this case the Matrikon OPC Explorer). In addition we have become acquainted with the Delphi programming language.

7 Discussion

Compared to traditional safety communication systems on oil and gas installations the ISS include some new features. Several subsystems are integrated into one common safety system, all data and audio are transported over one common network, and all the subsystems are operated from one or more common control panel. Another new feature is the use of OPC technology in such safety systems.

This thesis starts with a discussion of various proposals to an integrated safety solution. In chapter 2, six different solutions have been discussed; three IP solutions, two G.703 solutions and a combination solution. These proposals were conceived through brainstorming and various discussions on alternative solutions. The IP solutions are dependent on converting serial data to IP and vice versa. In section 2.2.2, we have discussed three different types of interface converters; ABB proprietary converters, PC based converters, and converters used in CCTV systems. The most adequate solution will probably be to use existing CCTV converters. This will probably result in the lowest costs since no equipment needs to be developed. Various CCTV converters have been suggested. Especially the audio quality provided by these converters has been discussed, since, according to the NORSOK standard, the PA system requires a 7 kHz audio signal. For the G.703 solutions it is probably most adequate to use existing ABB proprietary converters. By minor adjustment these converters will fulfill the requirements of the G.703 solutions.
The different proposals for an ISS were evaluated on criteria such as the number of converters and subsystems, available information on different equipment and technologies, redundancy, and reliability as described in section 2.5. To ensure redundancy and reliability various topologies were discussed. These topologies require a number of different subsystems and converters. The number of subsystems should be kept to an absolute minimum because of the limited space on installations, especially offshore installations. It turned out to be difficult to obtain information on some equipment and technical functions for some of the proposals. Based on these factors we discarded the different solutions one by one until we finally decided to continue the development of the combination solution. The combination solution is probably the most suitable proposal for the Integrated Safety System, because this solution has several advantages compared to the other solutions. Only one set of subsystem are required and no interface converters are needed. No use of converters will reduce the risk of failure related to the converters.

The G.703 technology is used for internal communication in the communication switch. We have also decided to use this technology for communication between the communication switch and the subsystems because of reliable and synchronized data transmission. All data received from the control panels will be distributed synchronized to all connected subsystems. This can not be guaranteed in an IP network where IP packets may be lost or received out of order, which may result in interference in redundant subsystems.

We have used OPC architecture for control and monitoring of the ISS. An OPC server is included in each communication switch and an OPC client is included in each control panel. Since OPC provides real-time communication, it is possible to take advantage of this technology. The OPC server includes all the information needed for operating the ISS. The functionality of the control panels change according to received status messages from the OPC servers.

One part of this thesis has been to design control panels capable of controlling several subsystems simultaneously from a common user interface. We also wanted the user interface to dynamically change setup, functionality and layout according to different system conditions, alarms and user inputs. For the operators, this will result in fewer and more user-friendly control panels. In addition, these control panels shall communicate over one common network which reduces the need for cabling on the installations compared to the current situations. To achieve this, we have made control panels based on a computer. A computer is capable of handling several tasks simultaneously, communicate over one common network, and provide possibility for connection of microphones and loudspeakers. In addition, a computer may provide different user interfaces; both a graphical user interface on a monitor, or by connected button panels. A graphical user interface on a touch screen is a simple and user-friendly solution, and is our main control panel solution. It turned out to be too difficult to make button panels with dynamically changing functionality and layout, so we decided to use panels based on existing button panels. Although, the settings on the button panels shall be controlled by the computer in the same way the touch screen panels. Making use of the OPC technology, the computer based control panels are able to read system information from the communication switches. Based on the system information, the control panels are able to automatically set alarms, select equipment, zones and channels, and to show the most important information in the user interface. This may reduce the time before alarms and messages are given and reduce the chance of human mistakes. This is a distinct improvement compared to the existing control panels where the operators have to select the right equipment, PA zones and UHF channels on their own. IP is a commonly used technology for communication between computers located on different locations on an Ethernet or on different Ethernets. We wanted to develop a solution that utilized this technology for communication between the control panels and the communication switches. This technology simplifies connection of additional IP compatible control panels and equipment. By using TCP/IP connection the ISS can be controlled from control panels located on other locations. For instance, if the ISS is implemented on an offshore oil installation, it is possible to control the system from control panels located on other installations, or even onshore.

Finally we should write proposals to new specifications or new revives of existing specifications describing the preferred solution. Since ISS is a new solution, we decided to write proposals to new specifications describing the different part of the solution. The structure of the ISS is divided into three sublevels, the operator panels, the communication switches and the subsystems. We have written four proposals to different specifications, one general specification providing a general overview of the ISS and three detailed specifications each describing the different sublevels of the ISS. We have not been able to get full control over all technical aspects of the different systems and equipment. This has resulted in a lack of technical descriptions in the specifications. Often, several people are involved in the writing of specifications to get a satisfying result. We have therefore focused on the functional and structural descriptions in the specifications.

Unfortunately we did not have enough time at the end this project to set up and test a demonstrator. The writing of the specifications was more demanding and time consuming then we firs predicted. Since the writing of the specification has been an ecclesial part of this thesis, we decided to improve these specifications instead of developing a demonstrator. Still we did some testing and preparation work on this demonstrator. As described in chapter 6, we developed a demo version of an OPC sever, written in Delphi programming language, and tested this against an OPC client developed by Matrikon.

8 Further work

This thesis is limited to the integration of the PA system and the UHF system. The TMS system is also included since it is needed for the system to work properly. Further work will be to integrate other subsystems like VHF, PABX, intercom and the entertainment system. This should not be too difficult based on the knowledge from the integration PA system and UHF system.

The PA subsystem consists of two main parts; a control part and an amplifier part. The control part deals with zone selection, communication to other systems and monitoring. Since the communication switches include all these functions, it should be possible to integrate the amplifiers with the communication switches. This should also be possible to the UHF base stations where the control part is done by the communication switch, and the radios are connected the same way as the stand-alone radios. This will result in a complete safety system where the subsystems are integrated into the centralized equipment, need of less equipment, fewer sources for errors and lower costs.

Our proposals to the functional design specifications may be extended with more detailed and technical information to satisfy the demands for functional design specifications.

9 Conclusion

Currently, safety systems on oil and gas installations consist of several separate communication systems. The intention is to integrate these systems into one common safety system communicating over one common network, and to control these systems from a common user interface. To limit the workload, this thesis describes the integration of the PA and UHF subsystems. In addition the TMS system has been included so these subsystems can work properly.

One part of this thesis has been to evaluate different proposals to a common transportation technology between the control panels and the subsystems. We were restricted by ABB to evaluate solutions based on TCP/IP or G.703 technologies, or solutions based on a combination of these two technologies. Six different solutions have been evaluated for this purpose; three TCP/IP solutions, two G.703 solutions and one combination solution. After comparing these proposals on various criteria such as number of converters and subsystems, available information, and reliability, we eliminated these solutions one by one until we decided to continue the development of the combination solution. The further development of the combination solution has resulted in the Integrated Safety System (ISS). The ISS currently consist of three different types of operator panels, two communication switches and several subsystems. The principal components of the ISS are the communication switches. The communication switches ensure reliable and synchronized data delivery between the connected equipment. This is made possible by including a switch matrix based on G.703 technology in each communication switch and by controlling and monitoring this matrix using an OPC server. The OPC technology provides real-time data exchange which makes it possible to control the ISS by using an OPC server and OPC client architecture. This is probably a new way of using the OPC technology. An OPC server, including all the OPC points needed to control and monitor the ISS, is included in each switch and OPC clients are included in the control panels. System changes are indicated by changes to the OPC point values on the OPC servers. The control panels will immediately respond to these changes, and depending on the status messages received, they will take actions such as automatically set alarms, select PA zones and UHF channels, and show the most important information in the user interface. The intention with this functionality is to help the operators to control the ISS, especially in critical situations.

Another part of this thesis has been to evaluate solutions on an integrated user interface intended used on touch screen or pushbutton control panels. The ISS includes three different operator panels; touch screen panels, pushbutton panels and microphone stations. Since designing a common pushbutton panel capable of controlling the subsystem turned out to be too complicated, we decided to use traditional pushbuttons for this propose. But instead of using hardwired control panels we have used computer based control panels. We have also designed a graphical user interface intended used on touch screen control panels. No changes are made to the microphone stations, except they are connected to both the communication switches.

Finally we should make proposals to detailed functional design specifications or revision existing specifications describing the ISS based on the selected transportation technology. The structure of the ISS is divided into three sublevels; the operator panels, the communication switches and the subsystems. We have written four different proposals to functional design specifications; one general specification providing an overview of the entire ISS and three detailed specifications each providing a detailed description on each of the three different sublevels of the ISS.

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Appendix

[A] General functional design specification – The Integrated Safety System

[B] General functional design specification – The communication switch

[C] General functional design specification – The operator panels

[D] General functional design specification – The subsystems

[E] The original thesis definition in Norwegian

[F] OPC software - source code [CD-ROM]